Geology of Chautauqua County, New York

PART I

Stratigraphy and Paleontology (Upper Devonian)

BY

IRVING H. TESMER

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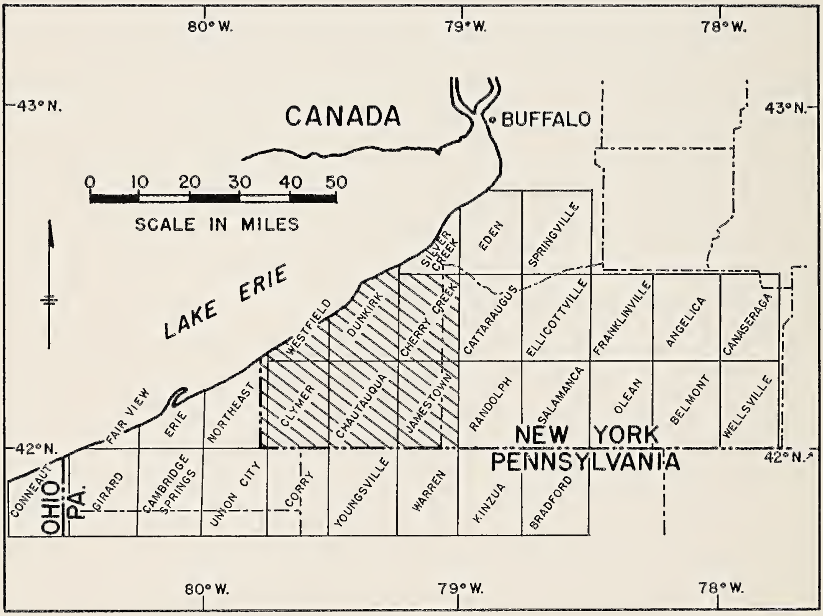

Figure 1. Index map showing location of Chautauqua County and quadrangles mapped

Stratigraphy and Paleontology (Upper Devonian) of Chautauqua County

BY

IRVING H. TESMER*

Abstract

Chautauqua County, southwestern New York, is underlain by 2,000 feet of predominantly marine shales, siltstones, and conglomerates of Late Devonian age. This sequence has been divided into five formations, some containing several members, whose distribution is illustrated on a geologic map of the county. Major rock units recognized in the area include, in ascending order, the Hanover, Canadaway, Chadakoin, Cattaraugus, and Knapp. Fossils are abundant only in the younger strata where brachiopods, pelecypods, bryozoans, and crinoid columnals are predominant. The regional structure appears to be that of a simple homocline, the beds dipping gently to the south or southwest, with only local modifications due to relatively minor structural features.

Introduction

Location

Chautauqua County occupies the southwestern corner of New York State and includes all or parts of seven 15-minute quadrangles (figure 1). This bulletin describes the stratigraphy and paleontology of Chautauqua County, exclusive of the Silver Creek quadrangle, as well as parts of Cattaraugus County which lie within the boundaries of the Cherry Creek and Jamestown 15-minute quadrangles. The Silver Creek quadrangle has been completed by de Witt and Colton (1953).

The described area lies between 79 degrees and 79 degrees 46 minutes west longitude, and 42 degrees and 42 degrees 31 minutes north latitude. In 1954, 7½-minute quadrangles of this area were published. However, most field work and mapping were based upon the earlier 15-minute maps.

Previous work in the region has been largely reconnaissance. The writer undertook a detailed study of the stratigraphy and paleontology of the lower part of the Canadaway Formation of Chautauqua County in 1947. Field work continued intermittently through the summer of 1959. The county is underlain by Upper Devonian marine shales, siltstones, sandstones, and conglomerates which are part of the Devonian Catskill Delta. Interpretation of the stratigraphy of the area is complicated by numerous lateral variations in lithology, the lack of good horizon markers, and the limited number of exposures. This report attempts to systematize the classification of the Upper Devonian rock units found in Chautauqua County and provides additional information concerning the stratigraphy and paleontology of these units. Some of the gross stratigraphic and paleontologic relations have already been presented (Tesmer, 1955; 1958).

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About 500 exposures of bedrock were observed and described, and some supplemental data have also been obtained from well cuttings (Tesmer, 1957). Elevations and measured sections of exposures were often determined with the aid of an altimeter.

The dip of the formations is usually less than 3 degrees south. The regional dip was computed geometrically by noting variations in the elevations of key horizons. The lower contacts of the black Dunkirk Shale and of the Laona and Shumla Siltstones served as key markers in the northern part of the area; to the south, the base of the Dexterville Siltstone was used. The Cattaraugus conglomerates have limited use as key units because of similar appearance, insufficient exposure, and variations in thickness and lithology.

Topography

The described area has a maximum relief of over 1,500 feet. Elevations range from 573 feet, the height of Lake Erie, to slightly over 2,160 feet in the Jamestown quadrangle. The region occupies portions of the Lake Erie Plain and Allegheny Plateau, which are separated by a relatively narrow, steep escarpment (figure 2).

The Lake Erie Plain varies from 2 to 4 miles wide. It is relatively flat, representing the floor of glacial lakes ancestral to Lake Erie. Considerable relief occurs on the Allegheny Plateau, except for the extensive flat bottoms of the valleys of Cassadaga and Conewango Creeks. The bedrock floors of these valleys are covered by thick glacial deposits.

The Allegheny or Portage Escarpment forms the northern border of the Allegheny Plateau. Its generally straight course is interrupted by the valleys of Chautauqua, Canadaway, Walnut, and Silver Creeks.

Topography is affected to a large degree by the configuration of the bedrock surface although glacial deposits have caused modifications, particularly in the larger valleys and in the vicinity of end moraines.

The glacial deposits have been discussed by MacClintock and Apfel

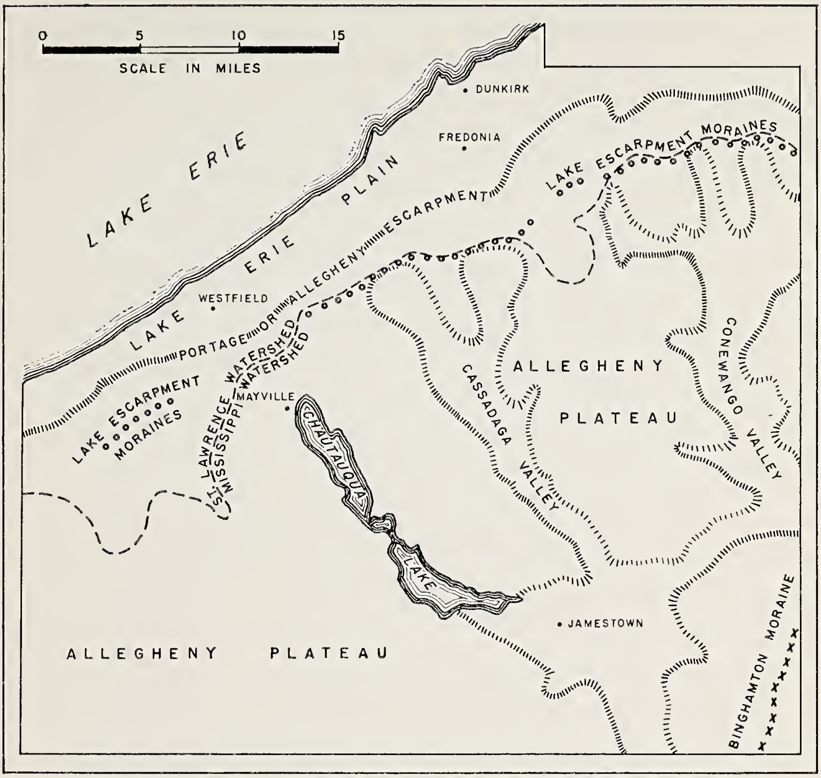


FIGURE 2. Major physiographic subdivisions of Chautauqua County, New York

(1944, pp. 1155-1161) and will be described in detail by Muller (manuscript in preparation). An end moraine, which may correspond to the Valley Heads Moraine of the Finger Lakes region, can be traced from Ripley to Perrysburg, roughly paralleling the crest of the Allegheny Escarpment. Leverett (1902, pp. 651-672) named these glacial deposits the Lake Escarpment Moraines, which Muller (1956, p. 13) considers Cary in age. Another prominent end moraine occurs along the east side of Conewango Valley in Carroll and Poland Townships in the Jamestown quadrangle. This Binghamton moraine abuts against drift-free uplands at about 2,000 feet above sea level. Two less extensive till sheets are also recognized by Muller (1956, p. 13). In the Clymer quadrangle, drumlins are numerous, varying from 50 to 80 feet high.

Drainage

The divide between the St. Lawrence and Mississippi watersheds runs roughly east-west through the described area (figure 2). Streams flowing northward into Lake Erie have gradients from 20 to over 300 feet per mile. The four major streams which flow northward are Chautauqua, Canadaway, Walnut, and Silver Creeks. These streams often have nearly vertical walls which are in places over 100 feet high. Most of the tributaries show well-developed dendritic drainage patterns, especially where they are eroding relatively thick morainal deposits, such as south of Shumla and Forestville.

Contrasting sharply are the major streams within the Mississippi watershed which have extremely small gradients, commonly 1 or 2 feet per mile. Conewango and Cassadaga Creeks exhibit many features of mature streams including extensive flood plains. These drain into the Allegheny River, then into the Ohio, and finally into the Mississippi River. Tributaries commonly have steep gradients.

Immediately south of the drainage divide between the St. Lawrence and Mississippi watersheds, all tributaries have gentle gradients and their courses are influenced by slight variations in topography. North of Cassadaga, Cottage, and Mud Lake, they commonly flow east or west, paralleling the Lake Escarpment Moraines. Immediately north of the divide, streams flow in a northerly direction.

The Westfield and Dunkirk quadrangles are bounded on the north by Lake Erie. Chautauqua Lake, which covers an area of almost 21 square miles, occupies a glaciated valley and drains into the Mississippi River via the Chadakoin, Allegheny, and Ohio Rivers. Smaller lakes within the described area include Findley, Bear, Mud, East Mud, Upper, Middle, and Lower Cassadaga Lakes, all part of the Mississippi watershed. Most of these small lakes occupy kettle holes which formed by the melting of ice blocks in the outwash south of the Lake Escarpment Moraines.

Several of the areas within the Mississippi watershed are poorly drained, as is shown by the presence of extensive areas of swampland, particularly in the Conewango Creek Valley. These swamps are developed on flat-lying glacial deposits that have a maximum thickness of over 500 feet. Some of the land has been reclaimed by means of drainage ditches.

Culture and Agriculture

The population of the described area is about half urban and half rural. Jamestown, 41,818, and Dunkirk, 18,205 (1960 census), are the largest communities. Villages with a population of over 2,500 include Falconer, Fredonia, Lakewood, Silver Creek, and Westfield. Many smaller villages occur within the region.

Two major types of farming are practiced. Along the Lake Erie Plain, the soil is well drained, and the surface is quite flat. Here, great quantities of tomatoes and grapes are raised and processed by canneries in the vicinity. On the Allegheny Plateau, dairying is the major type of farming. Many types of cattle fodder are grown in the area. In the rich soil of the Conewango Valley, lettuce and onions are raised in moderate amounts.

Major rail lines of the New York Central and Pennsylvania Railroads cross the Lake Erie Plain. A main line of the Erie Railroad passes through Jamestown. Branch lines connect the larger villages of the Allegheny Plateau.

Several important highways cross the area. The New York State Thruway, State Highway 5, and United States Highway 20 follow the plain which parallels the Lake Erie shoreline. These roads connect the Buffalo metropolitan area with the west. New York Highway 17 joins Westfield and Jamestown, and continues eastward to New York City. Major north-south roads include State Highway 76 from Ripley to Clymer, Highway 380 from Brocton to Jamestown, and Highway 60 from Dunkirk to Jamestown. Various other State and Federal highways traverse portions of the described area.

Many county roads are paved and in good condition, but town roads are usually dirt or gravel. In summer, town roads are usually passable.

Acknowledgments

The writer thanks the Geological Survey—New York State Museum and Science Service for the financial assistance which afforded the opportunity to study the stratigraphy and paleontology of Chautauqua County. Funds were also provided by the Geological Society of America and the Rutgers University Research Council, which aided in the preparation of the manuscript.

The writer has been fortunate in being able to consult with other geologists who have worked in southwestern New York. These men and their contributions to this study are gratefully acknowledged. The late George H. Chadwick contributed preliminary geologic maps and the location of significant exposures. F. D. Holland, Jr., University of South Dakota, furnished information on the fauna of the Knapp Formation, and the late Wilbert Hass, United States National Museum, supplied data on the distribution of conodonts in the area. James Pepper and Wallace de Witt, Jr., United States Geological Survey, contributed several measured sections of the Canadaway Formation. L. V. Rickard, Geological Survey, New York State Museum and Science Service, prepared the abstract, supervised the preparation of fossil plates, and took most of the field photographs.

Professors Louis W. Ploger, Earl T. Apfel, and Newton E. Chute,

Syracuse University, offered constructive criticism of considerable value. Miss Ruth Sparrow, research librarian at the Buffalo Museum of Natural Sciences, was very helpful in locating and lending reference material.

General Paleontology

Table 1 shows the various horizons at which a particular form has been collected within the described area. Data from adjacent quadrangles are not included, for in many cases the stratigraphic unit could not be determined.

Various types of index fossils are recognized in southwestern New York. There are forms (e.g., the brachiopods *Pugnoides duplicatus* and *Thiemella tenuilineata*) whose ranges are limited to a single or relatively few stratigraphic units. There are others (e.g., *Tylothyris mesacostalis*) which have a restricted teilzone or local stratigraphic range even though the biozone or total time-rock span may be considerably longer. Usually, an assemblage of forms, rather than a single species, is used for recognition of a certain unit (Greiner, 1957, pp. 40-60).

Brachiopods (e.g., *Ambocoelia gregaria*, *Camarotoechia contracta*, *Cyrtospirifer inermis*, and *C. nucalis*) constitute the greatest portion of the fauna in most places. However, most of the brachiopods have long ranges, so only a few species serve as good zone markers. Pelecypods are common in a few parts of the column. Conodonts are abundant at certain places and may aid in the correlation of the strata described in this report with the Devonian and Mississippian black shales of the interior of the United States and Canada. Other groups of fossils are poorly represented or not easily identified.

The stratigraphic distribution of fossils is irregular. The Hanover and the lower members of the Canadaway are often barren. Almost all the fauna is restricted to a few thin lenses, which sometimes contain prolific numbers of well-preserved specimens. The upper Canadaway, Chadakoin, and Cattaraugus contain a more widely distributed fauna, sometimes packed together to form lithified, calcareous, shell lenses called coquinites.

A lithofacies is the rock record of a particular sedimentary environment. Associated with each lithofacies in the area is a unique faunal assemblage. The black shales contain conodonts and pyritized algae. *Athyris*, *Productella*, *Strophalosia*, and *Mytilarca* are usually confined to siltstone beds, whereas some genera (e.g., *Chonetes*, *Leptodesma*, and *Palaeoneilo*) appear to be more common in gray argillaceous strata.

Some forms have a limited geographic distribution (Tesmer, 1955, p. 20). *Pugnoides duplicatus* and *Strophalosia hystricula* are common

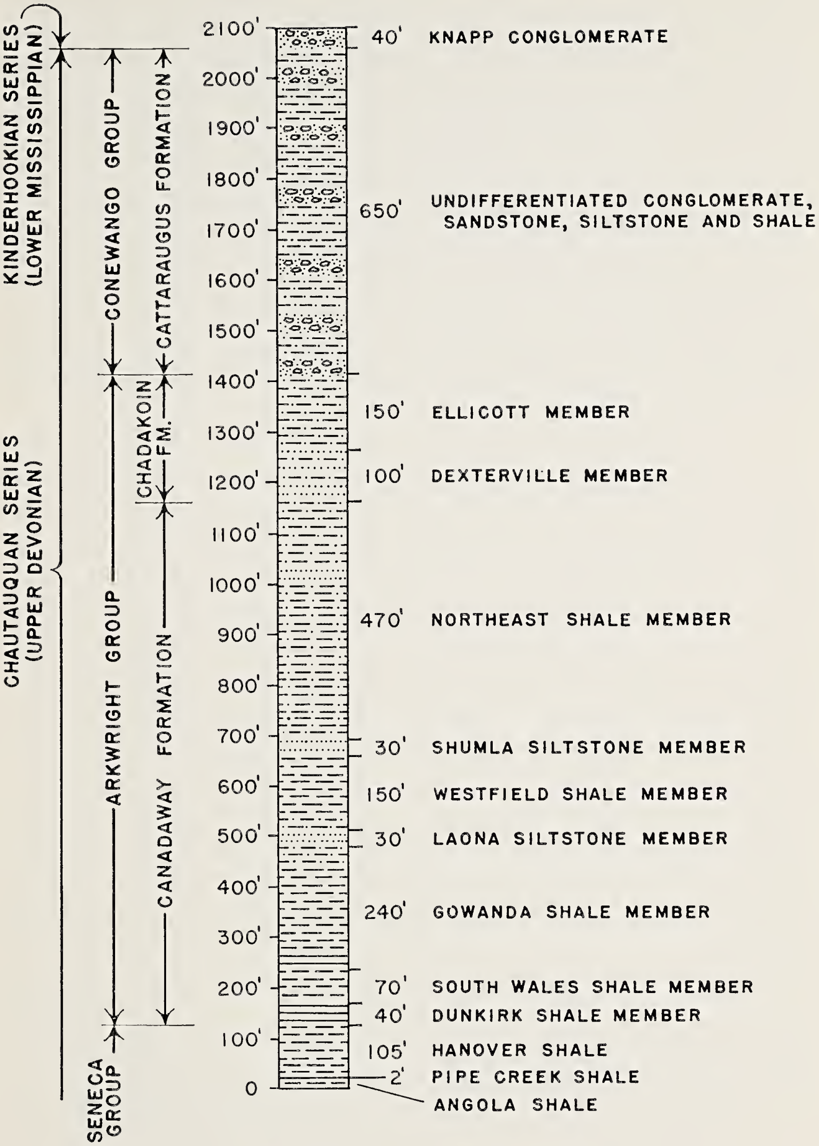


FIGURE 3. Generalized geologic column of Chautauqua County area

in Chautauqua and western Cattaraugus Counties, but have not been found east of this region. On the other hand, *Schellwienella chemungensis, Tylothyris mesacostalis*, and *Athyris angelica*, which are abundant in Cattaraugus and Allegany Counties, are not found to the west of a north-south line drawn through the middle of Chautauqua County. Factors restricting their migration probably were related to variations in sedimentation and accompanying bottom conditions, although other factors also may have been involved. Zone markers and faunal assemblages will be considered more thoroughly under the detailed stratigraphy and paleontology of the rock units.

Detailed Stratigraphy and Stratigraphical Paleontology

Upper Devonian (Chautauquan Series)

The name *Chautauquan Group* was proposed by Clarke and Schuchert (1899, p. 874) for Devonian "Chemung" and "Catskill" beds which are well exposed in Chautauqua County, N. Y. In the same paper, Clarke and Schuchert (p. 874) assigned the underlying rocks to the Seneca Group, for these are well shown in Seneca County, N. Y. The Seneca Group included the "Tully," "Genesee," and "Portage" beds.

Later workers (Caster, 1934, p. 62; Cooper, *et al.*, 1942, p. 1788) considered the Senecan and Chautauquan as Upper Devonian Series. Tesmer (1955, pp. 7-8) proposed the placement of all rocks of Late Devonian age in a single series, the Chautauquan, and the reduction of Senecan to a group lying within the Chautauquan Series, for present faunal evidence does not seem sufficient to warrant the usage of more than one Upper Devonian Series. This revised Chautauquan Series includes the Seneca, Arkwright, and Conewango Groups, in ascending order.

The base of the Upper Devonian in western New York was placed between the top of the Hamilton Group and the base of the Geneseo Shale (de Witt and Colton, 1953). Thus, the intervening Tully of central New York (Cooper, *et al.*, 1942, p. 1788) is of disputed Middle Devonian or Late Devonian age. Cooper placed the upper limit of unquestionable Devonian at the top of the Oswayo, but gave the age of the overlying Knapp as Devonian or Mississippian. Holland (1959, p. 1619), upon investigating the fauna of the Knapp and adjacent strata, considers the Knapp to be Mississippian. Therefore, the revised Upper Devonian Chautauquan Series includes all strata from the base of the Geneseo to the top of the Oswayo and may also include the older Tully.

Seneca Group

The term *Seneca Group* was proposed by Clarke and Schuchert (1899, p. 874) to include the "Tully," "Genesee," and "Portage" beds. In western New York, the Seneca Group is now considered to contain strata from the base of the Geneseo Shale to the base of the Dunkirk Shale (Tesmer, 1955, pp. 7-8).

West Falls Formation

The term *West Falls* was proposed as a formation name by Pepper, de Witt, and Colton (1956) to include the Cashaqua Shale, Rhinestreet Shale, and Angola Shale members exposed along the shore of Lake Erie. Only the youngest Angola Shale member crops out in Chautauqua County.

Angola Shale

The name *Angola* was first used by Clarke (1903, p. 24) for the soft gray shales between the older Rhinestreet and younger Dunkirk black shales. Good exposures occur near the village of Angola, Erie County, N. Y.

Later workers restricted the use of Angola. Chadwick (1923, p. 69) placed the Angola Shale between the Rhinestreet and younger Pipe Creek Shale, the usage accepted here. Pepper, de Witt, and Colton (1956) traced the Angola Shale eastward to Wyoming County, where it interfingers with the Gardeau, West Hill, and Nunda.

Only the upper foot or two of the Angola member may be seen within the described area. Soft gray shale may be found at the base of the Lake Erie cliffs, in the extreme northeast corner of the Dunkirk quadrangle. Eastward, in the adjacent Silver Creek quadrangle, the Angola is well exposed and has been described by de Witt and Colton (1953). It consists of about 225 feet of largely light gray to medium gray shale, with some interbedded grayish-black shale and numerous calcareous concretions.

Macrofossils are very scarce. Wilbert Hass of the United States National Museum reports (personal communication) conodonts from some of the grayish-black shale bands.

Java Formation

The name *Java Formation* was introduced by de Witt (1960, p. 1933) to include an older Pipe Creek Shale member and a younger Hanover Shale member. Both of these stratigraphic units can be seen in northeastern Chautauqua County along the Lake Erie shore.

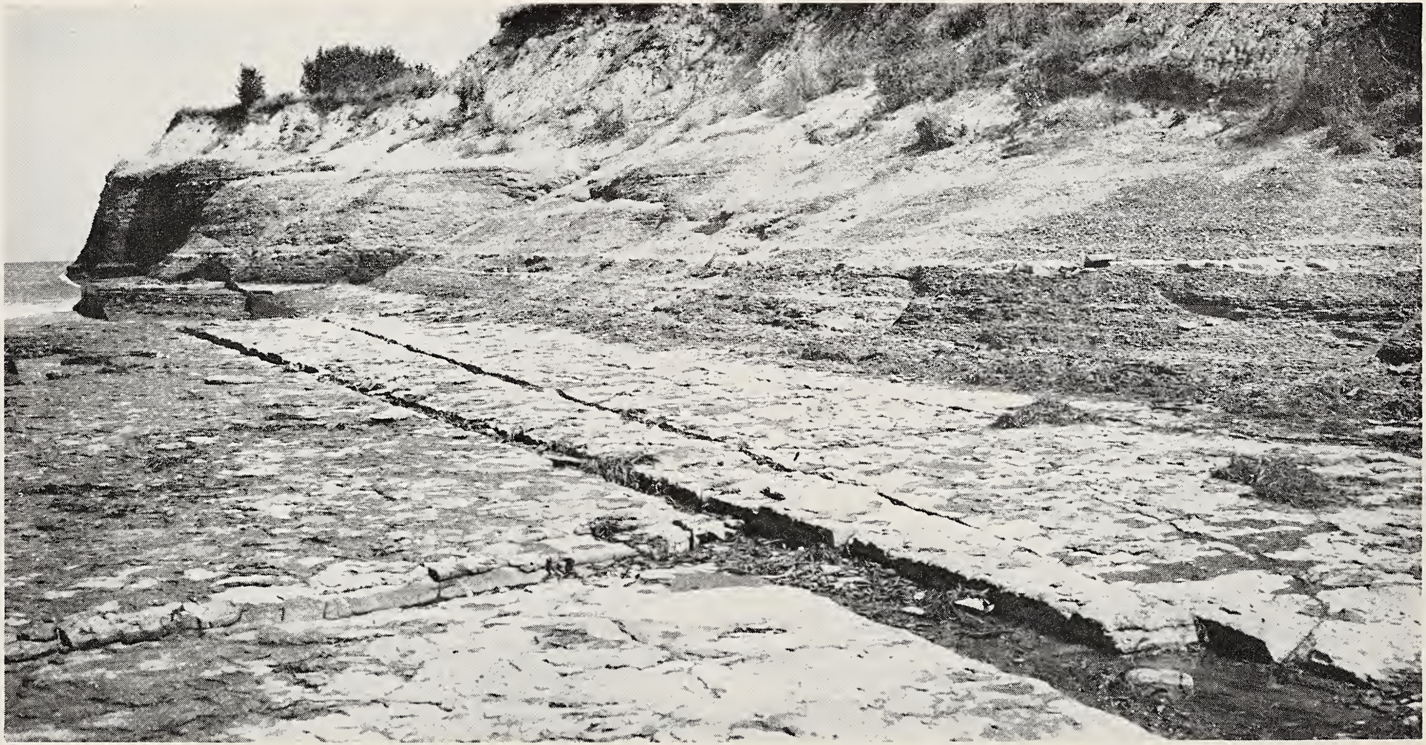


FIGURE 5. Hanover Shale along Lake Erie at Dunkirk, gray shale beds and thin limestone layers (locality 43)
Photograph by L. V. Rickard

Pipe Creek Shale

This unit was named by Chadwick (1923, p. 69) for dense black shale between older gray Angola Shale and younger gray Hanover Shale. The name is derived from Pipe Creek Glen, near West Falls, Erie County, N. Y.

Although the Pipe Creek Shale is relatively thin, it maintains a dark gray to black color and has been traced eastward from Lake Erie to the Genesee Valley (Pepper and de Witt, 1950). It also serves as an excellent key bed in subsurface stratigraphic correlation.

Exposures of the Pipe Creek, within the described area, are limited to the northeast corner of the Dunkirk quadrangle. Here, about 1 foot of grayish-black shale may be seen near the base of the Lake Erie cliffs. The unit is easily traced eastward into the adjacent Silver Creek quadrangle. Here, the Pipe Creek consists of 1 to 2 feet of fissile, grayish-black shale with traces of petroleum odor. Irregular masses of pyrite, from 1 to 4 inches long and one-quarter of an inch thick, may represent replaced marine algae. Carter (1945, p. 8) reports the fish *Leptosteus angustus* from the Pipe Creek of the Silver Creek quadrangle, and Wilbert Hass reports (personal communication) conodonts.

Hanover Shale

The name *Hanover Shale* was introduced by Hartnagel (1912, p. 76) for the gray shales beneath the black Dunkirk Shale. Excellent exposures occur in Hanover Township, northeastern Chautauqua County, in the Silver Creek quadrangle. Pepper and de Witt (1950) traced the Hanover Shale eastward toward the Genesee Valley, where it gradually merges with the Wiscoy Siltstone.

The Hanover Shale occurs along the Lake Erie cliffs from Point Gratiot in the city of Dunkirk to the northeast corner of the Dunkirk quadrangle. It is also exposed in the lower parts of the valleys of Scott and Beaver Creeks.

The Hanover consists of about 90 feet of largely light gray to medium gray shale with some interbedded grayish-black shale, light gray arenaceous shale, argillaceous limestone, and calcareous concretions, ranging from less than 1 inch to over 3 feet in diameter. Barite crystals and dessication cracks partially filled with calcite have been noted.

Within the described area, Hanover fossils are mostly limited to pyritized algae. De Witt and Colton (1953) report the cephalopod *Manticoceras* cf. *pattersoni* from the Hanover of the Silver Creek quadrangle, and Hass (1958, p. 766) reports the conodonts *Palmatolepis subrecta* and *Ancyrognathus euglyphea* from the Hanover of western New York.

PLATE 1

Arkwright Fossils

A. *Praecardium multicostatum* Clarke, left valve. Hanover Township. Gowanda index fossil. Locality 117 N.Y.S.M. 11426.

B. *Aulatornoceras clarkei* (Miller). Hanover Township. Gowanda index fossil. Locality 65 N.Y.S.M. 11427.

C. *Athyris* sp., pedicle valve. Hanover Township. Laona. Locality 119 N.Y.S.M. 11428.

D. *Petrocrania* cf. *leonis* (Hall). Hanover Township. Laona. Locality 119 N.Y.S.M. 11429.

E. *Thiemella tenuilineata* (Hall). Hanover Township. Northeast. Locality 820 N.Y.S.M. 11430.

F. *Cariniferella tioga* (Hall). Hanover Township. Laona. Locality 119 N.Y.S.M. 11431.

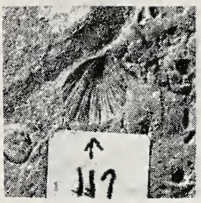
G. *Cyrtospirifer inermis* (Hall), pedicle valve. Cherry Creek Township. Northeast. Locality 722 N.Y.S.M. 11432.

H. *Tylothyris mesacostalis* (Hall). Hanover Township. Laona. Locality 119 N.Y.S.M. 11433.

I. *Edmondia* cf. *philipi* Hall. Hanover Township. Laona. Locality 119 N.Y.S.M. 11434.

J. Bryozoan. Hanover Township. Laona. Locality 119 N.Y.S.M. 11435.

(All figures are natural size.)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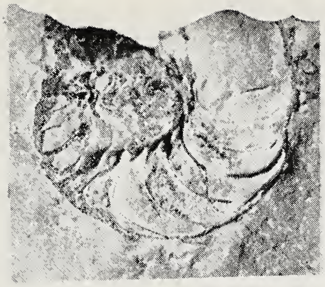
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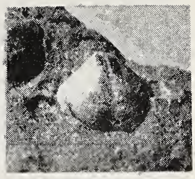
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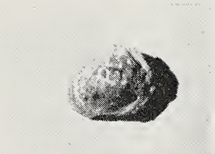
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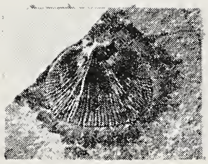
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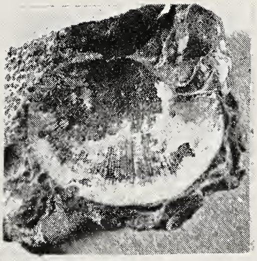
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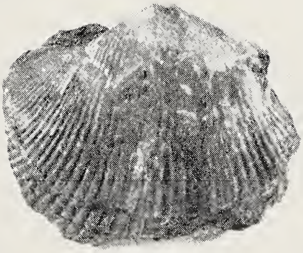
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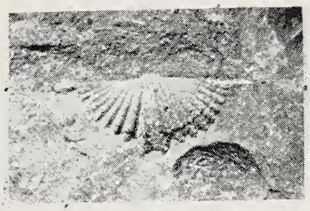
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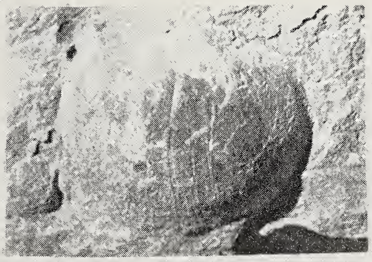
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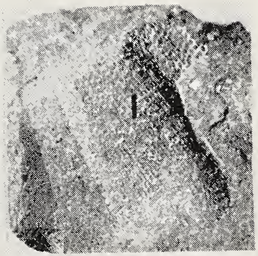
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Arkwright Group

The term *Arkwright Group* was proposed and described by Tesmer (1955, pp. 9-18) for 1,500 feet of strata between the base of the Dunkirk Shale and the top of the Ellicott Shale. The type locality is in Arkwright Township, Chautauqua County, in the Dunkirk and Cherry Creek quadrangles. The group is divided into two formations, the Canadaway and Chadakoin. The Arkwright Group is fully exposed within the described area. Fossils are illustrated in plates 1-3.

CANADAWAY FORMATION

The term *Canadaway* was proposed as a group name by Caster (1934, p. 136, footnote), but it is now used as a formation name (Tesmer, 1955, p. 9). The type locality is along Canadaway Creek, Dunkirk quadrangle. Here, the Canadaway consists of about 1,000 feet of strata. Seven members are distinguished; in ascending order, the Dunkirk, South Wales, Gowanda, Laona, Westfield, Shumla, and Northeast. The "Perrysburg" Formation, proposed by Pepper and de Witt (1951) to include only the Dunkirk, South Wales, and Gowanda members, is not used (Tesmer, 1955, p. 9). The base of the Canadaway is marked by 40 feet of black Dunkirk Shale. The top of the formation is usually marked by the introduction of gray siltstones containing the brachiopod *Pugnoides duplicatus,* assigned to the Dexterville Member of the Chadakoin Formation. The relatively rare pelecypod genera *Elasmatium, Euthydesma, Kochia,* and *Loxopteria* appear to be restricted to the Canadaway. See Chadwick (1935b, pp. 323-326). The pelecypods *Crenipecten* and *Pteronites* first appear in the Canadaway, whereas *Lunulicardium, Ontaria,* and *Praecardium* do not seem to occur above it.

One of the best exposures of the lower part of the Canadaway Formation is along Walnut Creek, in the Silver Creek and Cherry Creek quadrangles between the villages of Silver Creek and Forestville, from 680 to 910 feet above sea level. An excellent exposure of the middle Canadaway occurs along a small tributary to Scott Creek, known as Smith's Ravine, near the eastern edge of the Dunkirk quadrangle, about 4 miles southeast of Dunkirk, between 850 and 1,120 feet above sea level.

The upper part of the Canadaway Formation is widely exposed within the described area. Its members vary in thickness, lithology, and faunal content, so that no one section is entirely representative. A fairly typical section has been measured along Chautauqua Creek. (See measured section of Northeast Shale in the appendix.)

Dunkirk Shale Member

The name *Dunkirk* was proposed by Clarke (1903, p. 24) for the black shales exposed at Dunkirk, N. Y., between strata now known as the Hanover Shale and the South Wales Shale. The type locality is along the cliffs on Lake Erie at Point Gratiot, within the city of Dunkirk. Pepper and de Witt (1951) have traced the black Dunkirk Shale eastward beyond the Genesee Valley to Hornell. The Dunkirk maintains a rather constant lithology, but thins to the east.

Exposures occur along Lake Erie in the Dunkirk quadrangle, from Van Buren Point to Point Gratiot, and in the valleys of Scott and Beaver Creeks in Sheridan Township. In the Dunkirk quadrangle, this rock unit is represented by about 40 feet of massive medium gray to grayish-black shale. Near the middle occurs a bed of calcareous septaria, averaging between 2 and 3 feet in diameter. Pyritized algae, carbonized plant stems (Pepper and de Witt. 1951), and conodonts (Hass, 1951, p. 2536) have been noted.

South Wales Member

Pepper and de Witt (1951) subdivided the Gowanda of Chadwick (1919, p. 157) into two units, an older South Wales and a younger Gowanda (restricted). The type locality of the South Wales occurs on a small tributary to the east branch of Cazenovia Creek, 3 miles south of South Wales, Springville quadrangle. The member has been traced from the Lake Erie shore, in the vicinity of Van Buren Point in the Dunkirk quadrangle, eastward to Cameron, N. Y., in the Woodhull quadrangle.

Within the described area, the South Wales Member varies from about 60 to 80 feet thick. The unit consists of medium light gray to medium dark gray shale, with some interbedded dark gray shale and light gray siltstone. Some of the medium gray shale beds contain calcareous concretions up to 3 feet in diameter. The siltstones and most of the shales are thin bedded, although some of the medium gray shale beds are more blocky, especially when weathered.

South Wales exposures occur along Lake Erie near Van Buren Point, along Canadaway Creek in Dunkirk Township, near the headwaters of Beaver Creek, and along Walnut Creek near the northern edge of the Cherry Creek quadrangle. Much of the area of outcrop of the South Wales is covered by glacial lake deposits, so that rock exposures are generally limited to stream cuts and lake cliffs.

In addition to algae, Hass (1958, p. 767) reports the conodonts *Ancyrognathus bifurcata* and *Palmatolepis glabra* from the South Wales in the adjacent Silver Creek quadrangle. Most of the beds are barren.

PLATE 2

Arkwright Fossils

A. *Athyris angelica* Hall, pedicle valve. Cherry Creek Township. Dexterville. Locality 275 N.Y.S.M. 11436.

B. *Camarotoechia contracta* (Hall). Cherry Creek Township. Dexterville. Locality 275 N.Y.S.M. 11437.

C. *Productella lachrymosa* (Conrad). Leon Township. Dexterville. Locality 621 N.Y.S.M. 11438.

D. *Productella speciosa* Hall. Leon Township. Dexterville. Locality 621 N.Y.S.M. 11439.

E. *Pugnoides duplicatus* (Hall). Cherry Creek Township. Dexterville index fossil. Locality 275 N.Y.S.M. 11440.

F. *Thiemella tenuilineata* (Hall). Leon Township. Dexterville. Locality 621 N.Y.S.M. 11441.

G. *Strophoproductus hystriculus* (Hall). Leon Township. Dexterville. Locality 278 N.Y.S.M. 11442.

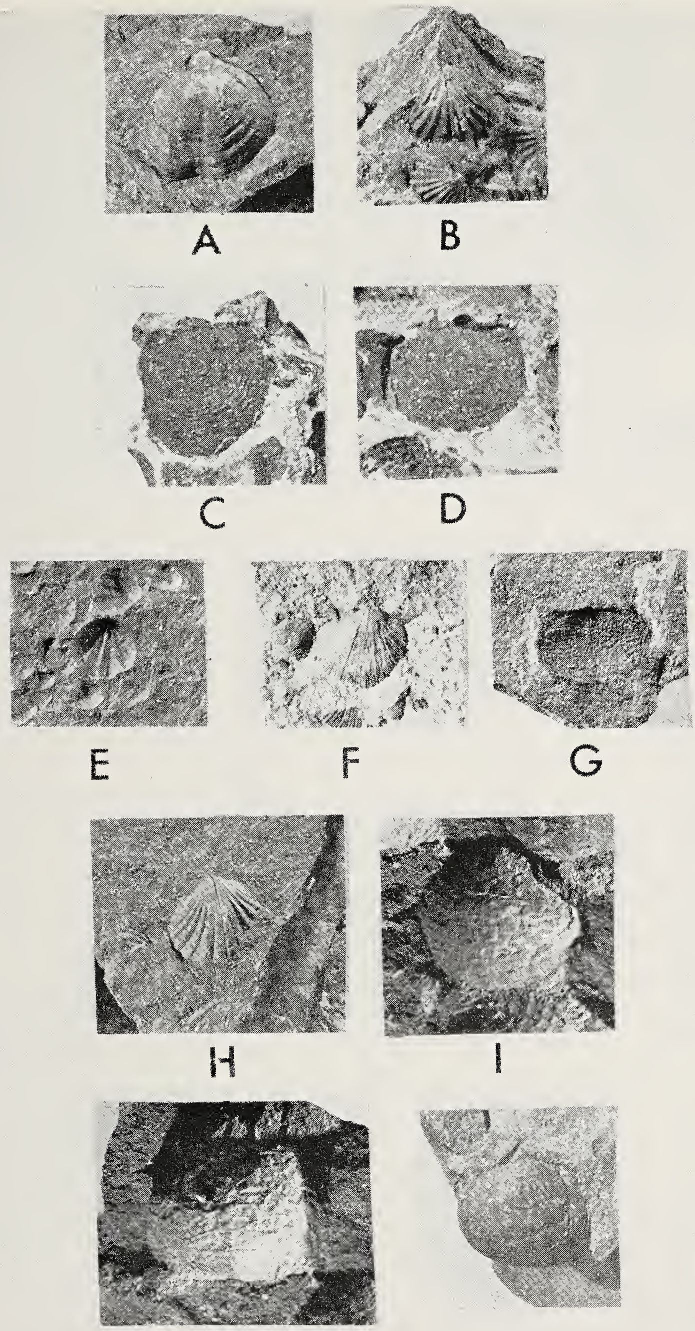
H. *Camarotoechia contracta* (Hall). Cherry Creek Township. Ellicott. Locality 868 N.Y.S.M. 11443.

I. *Productella* sp. Cherry Creek Township. Ellicott. Locality 745 N.Y.S.M. 11444.

J. *Productella* cf. *hirsuta* Hall. Cherry Creek Township. Ellicott. Locality 745 N.Y.S.M. 11445.

K. *Productella* cf. *speciosa* Hall. Charlotte Township. Ellicott. Locality 727 N.Y.S.M. 11446.

(All figures are natural size.)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Gowanda Member

Originally, Chadwick (1919, p. 157) included the strata between the top of the Dunkirk Shale and the base of the Laona Siltstone in the Gowanda. Pepper and de Witt (1951) proposed a division of the original unit into an older South Wales Member and a younger restricted Gowanda Member. At the base of the Gowanda is a relatively prominent band of dark gray shale, from 5 to 15 feet in thickness.

The type locality for the Gowanda is along Cattaraugus Creek (Chadwick, 1924, p. 150). Pepper and de Witt (1951) stated that neither the base nor the top of the unit may be determined at the type locality, nor has the top of the Gowanda been found east of Little Indian Creek at the northeast corner of the Cherry Creek quadrangle. As an almost complete section of the Gowanda, showing both lower and upper contacts, is exposed along Walnut Creek in the vicinity of Forestville, the present author suggests this exposure as a Gowanda reference section. The Gowanda-Laona contact has not been traced eastward from the region considered in this bulletin.

The Gowanda varies in thickness from about 120 feet (west edge of Dunkirk quadrangle) to over 230 feet (east edge of Cherry Creek quadrangle). Some of this variation may be due to a short period of erosion before deposition of the overlying Laona Siltstone. The Gowanda consists of medium light gray to medium gray shale with some light gray arenaceous shale, dark gray shale, and some light gray siltstone beds up to 3 inches in thickness. Bands of calcareous or silty concretions and septaria, which range from about 1 inch to more than 1 foot in diameter, are present. Some concretionary zones may be traced for distances of several miles, but cannot be used for long-distance correlations.

Excellent exposures are numerous throughout the northern portion of the Dunkirk and Cherry Creek quadrangles. The member can be traced from Lake Erie cliffs, in Portland Township, eastward along Slippery Rock and Canadaway Creeks to Walnut Creek, on the Cherry Creek quadrangle. Other excellent exposures of the Gowanda occur in valleys cut by Silver, Big Indian, and Little Indian Creeks.

Luther (1903, p. 1026) reported fossiliferous zones with cephalopods and large pelecypods (in the Gowanda) along Walnut Creek near the Erie Railroad bridge at Forestville. The present writer found the cephalopod *Aulatornoceras clarkei* and pyritized algae in the vicinity, but is uncertain as to the exact location of Luther's zones. Clarke (1904) described several forms from the Gowanda, listed below, which may have come from the same locality described by Luther. The writer collected *Praecardium multicostatum* along Silver Creek from strata believed to be nearly equivalent to the above.

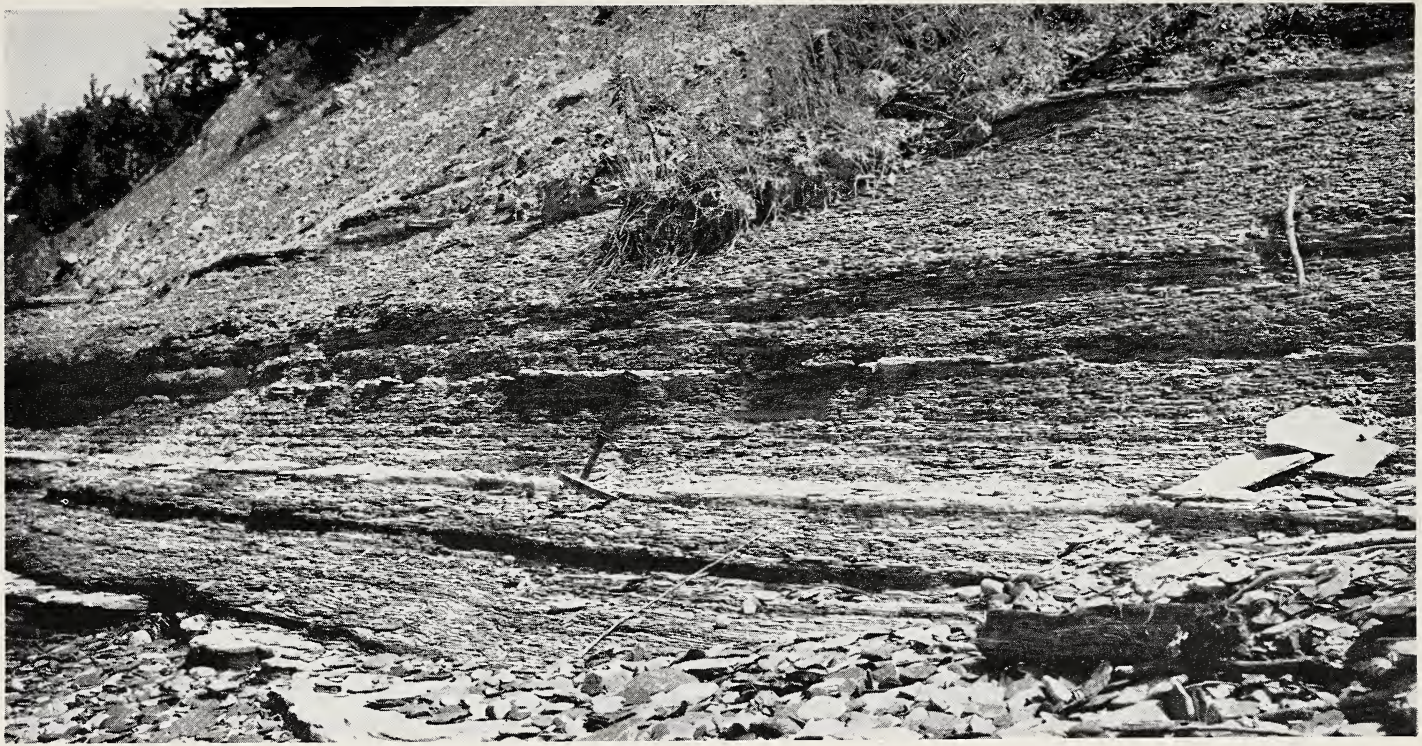


FIGURE 6. South Wales Shale along Lake Erie in Portland Township, Dunkirk quadrangle, interbedded black and gray shales with some thin interbedded siltstones (locality 1,540) *Photograph by L. V. Rickard*

PLATE 3

Arkwright Fossils

A. *Aviculopecten cancellatus* Hall, right valve. Leon Township. Dexterville. Locality 278 N.Y.S.M. 11447.

B. *Palaeanatina* cf. *angusta* Hall, left valve. Arkwright Township. Dexterville. Locality 714 N.Y.S.M. 11448.

C. *Sanguinolites* cf. *undulatus* Hall, left valve. Leon Township. Dexterville. Locality 621 N.Y.S.M. 11449.

D. *Mytilarca chemungensis* (Conrad). Leon Township. Dexterville. Locality 278 N.Y.S.M. 11450.

E. *Pterinopecten* sp. Cherry Creek Township. Dexterville. Locality 746 N.Y.S.M. 11451.

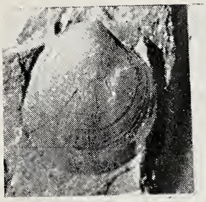
F. *Straparolus* cf. *hecale* Hall. Leon Township. Dexterville. Locality 278 N.Y.S.M. 11452.

G. Crinoid stem. Leon Township. Dexterville. Locality 860 N.Y.S.M. 11453.

H. *Leptodesma* cf. *potens* Hall, left valve. Cherry Creek Township. Ellicott. Locality 868 N.Y.S.M. 11454.

I. *Callixylon* cf. *newberryi* Elkins and Wieland. Charlotte Township. Ellicott. Locality 744 N.Y.S.M. 11455.

(All figures are natural size.)



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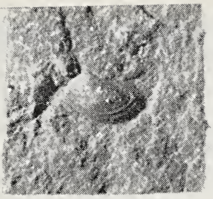

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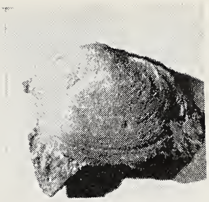

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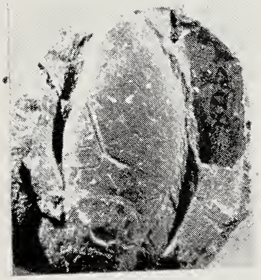

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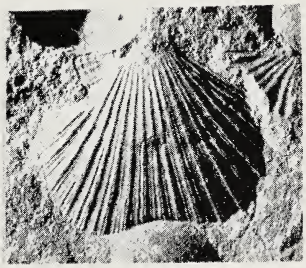

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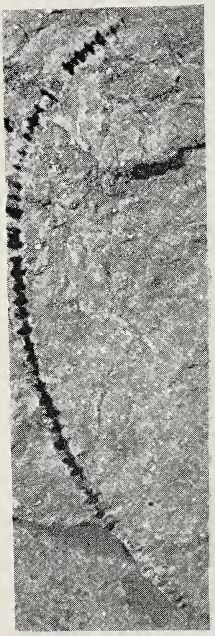

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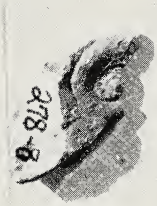

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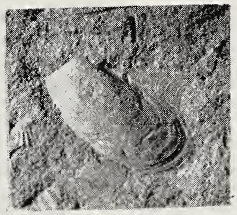

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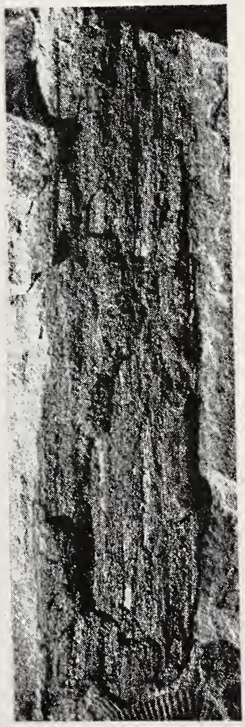

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Species which appear to be restricted to the Gowanda are as follows:

PORIFERA (?)

Clionolithes palmatus Clarke

GASTROPODS

Euryzone itylus (Clarke)
Loxonema danai Clarke

CEPHALOPOD

Aulatornoceras clarkei (Miller)

PELECYPODS

Elasmatium gowandense Clarke
Euthydesma subtextile Hall
Kochia ungula Clarke
Loxopteria corrugata Clarke
L. dispar (Sandberger)
L. intumescentis Clarke
L. laevis Frech
L. vasta Clarke
Lunulicardium absegmen Clarke
L. eriense Clarke
L. furcatum Clarke
Palaeoneilo linguata Clarke
Praecardium multicostatum Clarke
P. vetustum Hall

CRINOID

Scytalocrinus ornatissimus (Hall)

Hass (1958, p. 767) reports these conodonts from the upper Gowanda bed of Perrysburg Township, along a tributary to Big Indian Creek:

Ancyrognathus bifurcata (Ulrich and Bassler)
Palmatolepis glabra Ulrich and Bassler
P. perlobata Ulrich and Bassler
P. subperlobata Branson and Mehl

Palmatodella delicatula Ulrich and Bassler was collected from the upper Gowanda along Little Canadaway Creek at Lamberton, in Pomfret Township.

The author collected the following from Correll's point, along the Lake Erie shore at the western edge of the Dunkirk quadrangle:

PELECYPODS

Euthydesma subtextile Hall
Praecardium vetustum Hall

CEPHALOPODS

"Orthoceras" sp.
coiled forms

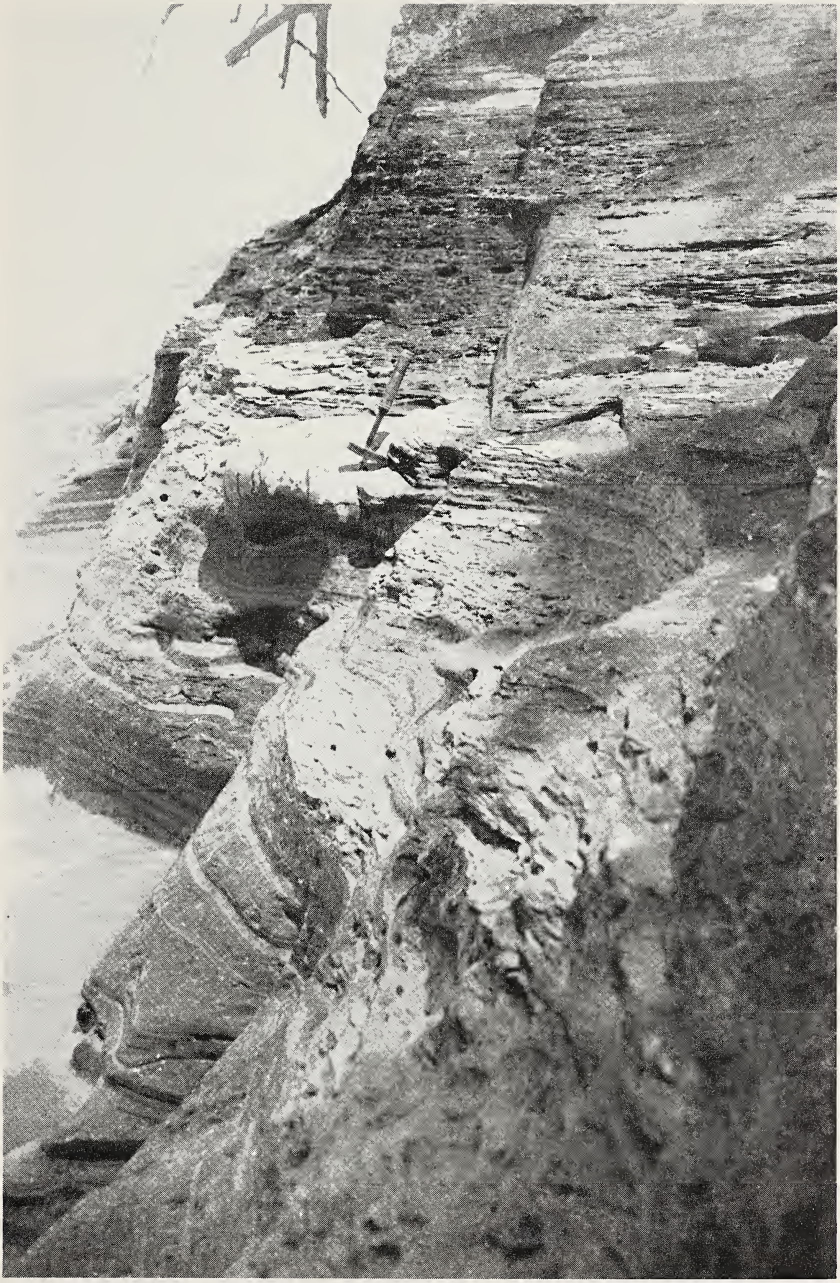


FIGURE 7. Gowanda Shale along Lake Erie in Portland Township, Dunkirk quadrangle, gray shales containing large calcareous concretions (locality 1,162) *Photograph by L. V. Rickard*

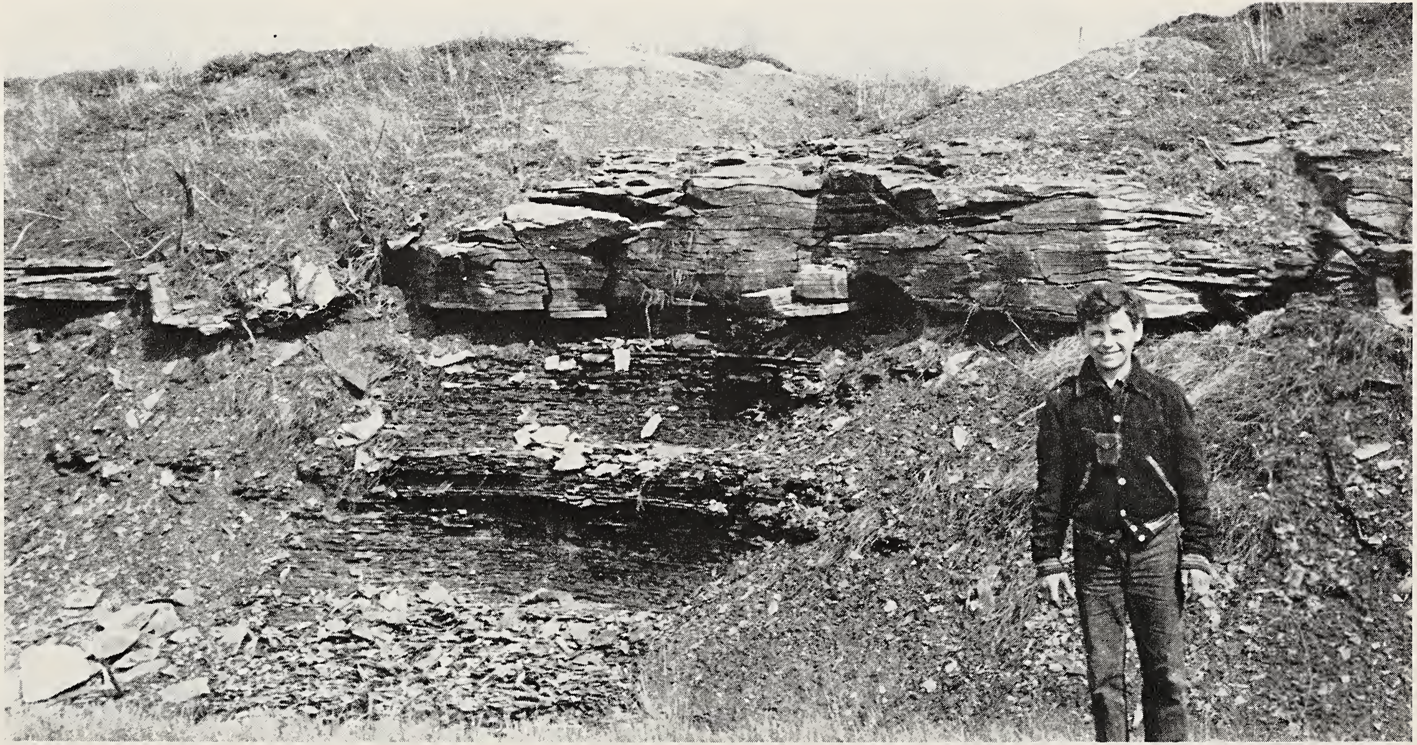


FIGURE 8. Contact between the Gowanda Shale and the overlying Laona Siltstone

Laona Siltstone Member

Bedrock quarried near Laona, N. Y., was named Laona Sandstone by Beck (1840, p. 57). The rock is more properly a siltstone, as the grain size lies within the silt range (1/16 to 1/256 mm.). The Laona has been traced from Lake Erie exposures near Barcelona, in the Westfield quadrangle, to the eastern edge of the Cherry Creek quadrangle along Little Indian Creek. The silty beds seem to pinch out to the east of the latter locality, and the intervening shaly beds of the Laona merge with the shales of the overlying and underlying members.

The Laona varies from 3 feet near Barcelona to about 25 feet near the eastern edge of the Dunkirk quadrangle. The base serves as a key horizon in the northern part of the Dunkirk and Cherry Creek quadrangles, and may show some minor shallow structures. The lower portion of the unit consists largely of light gray quartzose siltstones up to 1 foot thick, with interbedded gray shales increasing toward the top and to the east. The Laona grades into the overlying Westfield Member. The upper contact is placed where shales become dominant.

Exposures of the Laona are very common because siltstones are more resistant than shales. The member serves as a cap rock for waterfalls, some of which reach 30 feet or more. Exposures occur near the mouth of Chautauqua Creek at Barcelona, along many unnamed streams between Barcelona and Brocton close to the lake shore, along Slippery Rock Creek at Brocton, in the valley of the unnamed stream immediately south of Lamberton, and along Canadaway Creek at Laona eastward to the edge of the Dunkirk quadrangle, where the base is exposed about 890 feet above sea level. In the Cherry Creek quadrangle, the Laona Siltstone, with variable amounts of interbedded gray shale, crops out in the valleys of Walnut, Silver, Big Indian, and Little Indian Creeks, as well as along many of their tributaries. Road cuts are common, one of which is 1.5 miles south of the village of Sheridan; another is at Smith Mills Station.

The pelecypod *Praecardium melletes* was reported by Clarke (1904, p. 307) from a horizon believed to be Laona. The writer has collected the following along a small tributary to Silver Creek, 1.5 miles north of Nashville:

BRYOZOANS

Numerous forms

BRACHIOPODS

Ambocoelia gregaria Hall
Athyris angelica Hall
Chonetes cf. *lepidus* Hall
Cyrtospirifer sp.

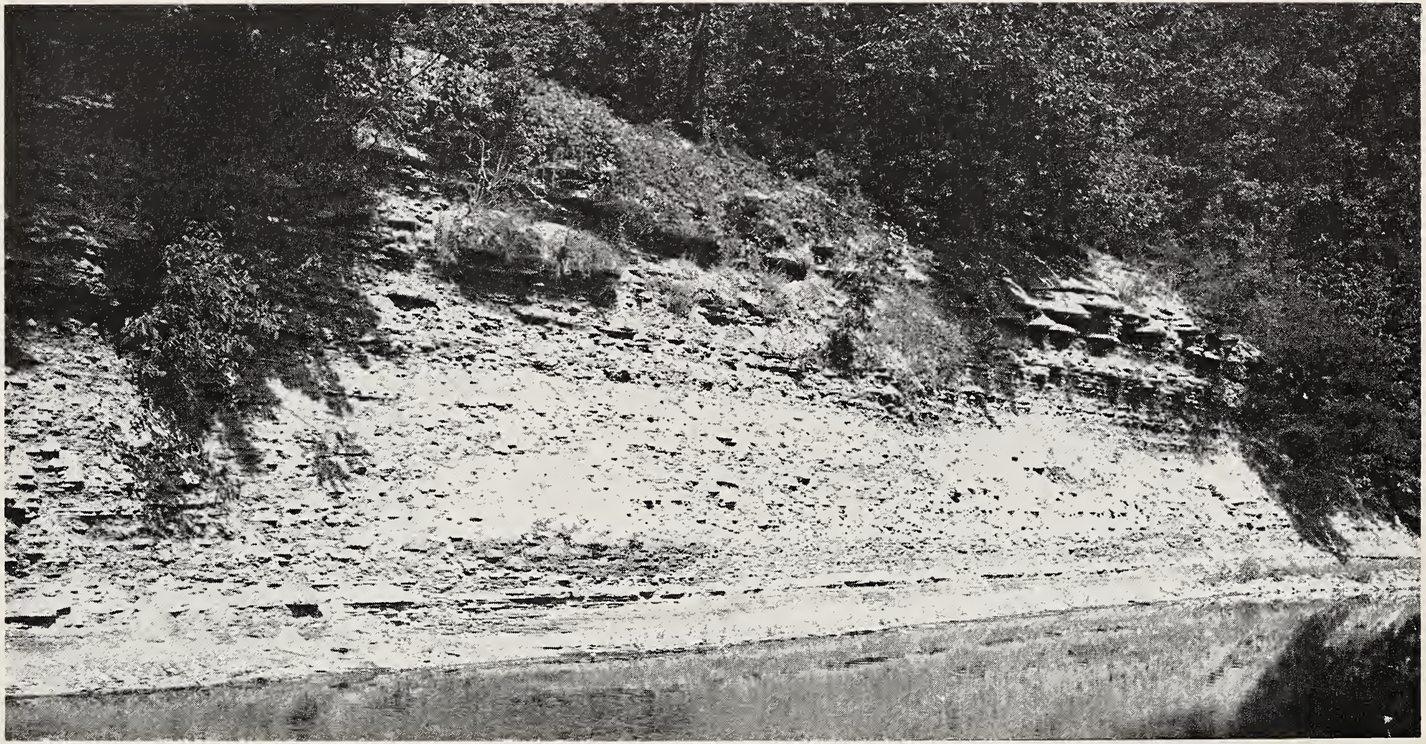


FIGURE 9. Westfield Shale near mouth of Chautauqua Creek in Westfield Township, soft gray shales with a few interbedded siltstones (locality 105) *Photograph by L. V. Rickard*

Petrocrania cf. *leonis* (Hall)
Strophalosia hystricula (Hall)
Tylothyris mesacostalis (Hall)

PELECYPODS

Edmondia cf. *philipi* Hall
Mytilarca chemungensis (Conrad)
Pteronites profundus Hall
Sphenotus cf. *contractus* Hall

CRINOIDS

Columnals

FISH

Several fragments

This is the only locality where Laona fossils were found in place. Loose slabs of light gray siltstone found near Forestville, believed to be Laona, contain many similar species.

The Laona fauna consists largely of brachiopods, although pelecypods are moderately abundant. Fossils seem limited to a thin discontinuous zone within a foot or two of the base of this member. These forms contrast with the underlying Gowanda species, which are largely pelecypods and include no brachiopods. Thus far, no species have been found which are common to the Gowanda and Laona. The author believes the two assemblages are both lithofacies faunas, one of which inhabited a muddy portion of the ocean floor and the other a silty portion. A time difference might also be partly responsible.

Praecardium melletes, a rare pelecypod, is the only form limited to the Laona, but this unit may also be detected by the first appearance of the following:

BRACHIOPODS

Athyris angelica Hall
Petrocrania leonis (Hall)
Strophalosia hystricula (Hall)
Thiemella tenuilineata (Hall)

PELECYPODS

Mytilarca chemungensis (Conrad)
Pteronites profundus Hall
Sphenotus contractus Hall

Westfield Shale Member

Chadwick (1923, p. 69) first used the name *Westfield Shale* for a series of mostly medium gray shales between the Laona and Shumla Siltstones. The type locality is along Chautauqua Creek at the village of Westfield, N. Y. This shale has been traced along the Lake Erie shore from near the New York-Pennsylvania State line eastward to the eastern

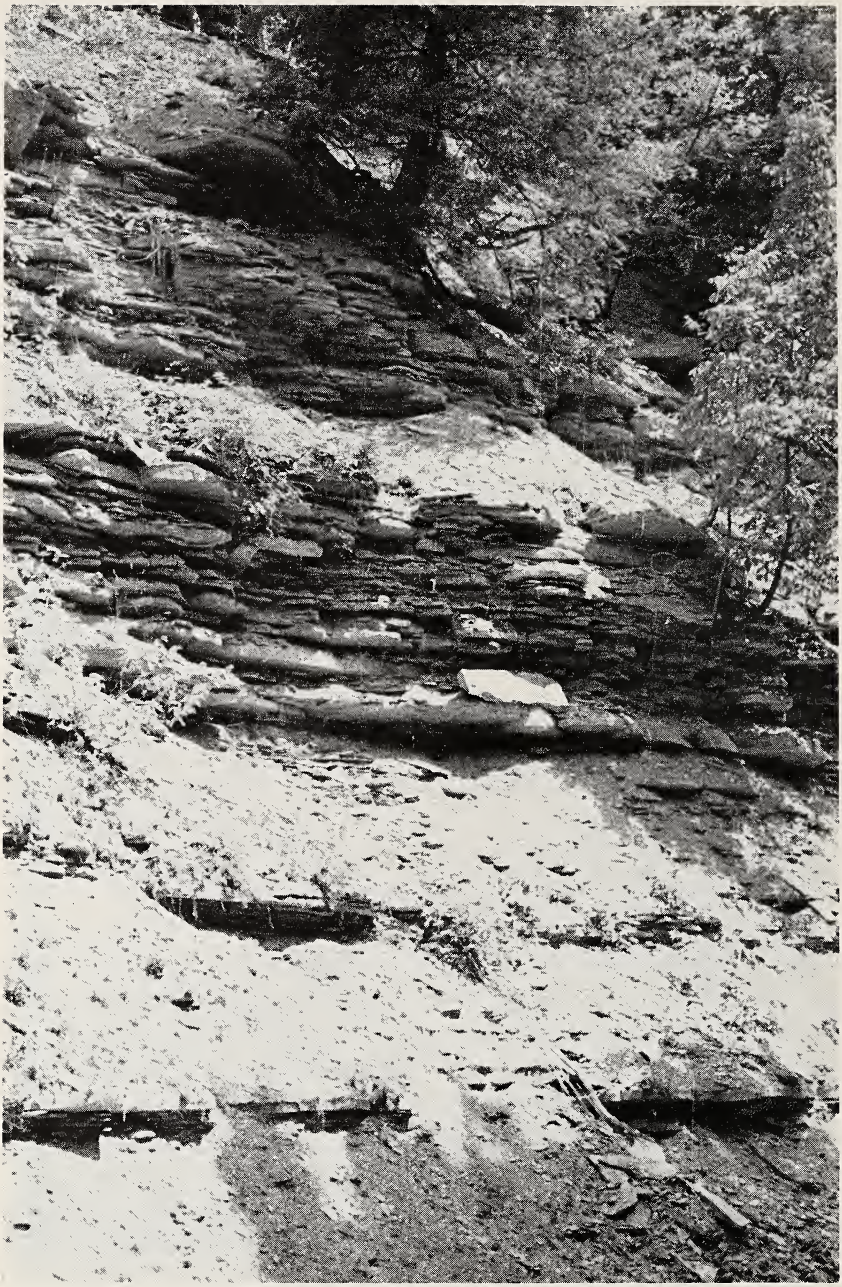


FIGURE 10. Contact between the Westfield Shale and the overlying Shumla Siltstone along Canadaway Creek at Shumla

edge of the Cherry Creek quadrangle, about 2 miles north of Perrysburg.

The Westfield Shale ranges from about 100 feet to about 220 feet. It is composed of medium gray shales with a few interbedded siltstone layers, a fraction of an inch to 1 foot in thickness. In many of the Cherry Creek quadrangle exposures, the lower part of the Westfield contains a few beds of large concretions about a foot in diameter.

The relatively high percentage of shale within the Westfield Member allows easy weathering and erosion. Outcrops are most common where erosion and downcutting are rapid. Good exposures occur along the Lake Erie shore between the State line and Barcelona, along Chautauqua Creek between Barcelona and the village of Westfield, along Slippery Rock Creek near Brocton in the Dunkirk quadrangle, in the valley of the unnamed stream south of Lamberton, along Canadaway Creek between Laona and Shumla, and in the valley of a small tributary to Scott Creek in Sheridan Township, near the eastern edge of the Dunkirk quadrangle, where the member is about 175 feet thick. In the Cherry Creek quadrangle, good Westfield exposures may be seen along Tupper Creek, some of the tributaries to Silver Creek, and a tributary to Big Indian Creek east of the main stream. Other outcrops occur in road cuts, such as on the Sheridan-Arkwright highway, from 1.5 to 2 miles south of the village of Sheridan.

A fossiliferous horizon exists 100 feet upstream from where the Erie Railroad bridge crosses a tributary to Silver Creek, about a mile north of Nashville in the Cherry Creek quadrangle. *Camarotoechia contracta* and carbonized plant stems were collected.

Hass (1958, p. 767) reports the following conodonts from Westfield Shale exposures, along Little Canadaway Creek a half mile south of Lamberton, in the Dunkirk quadrangle:

Ancyrognathus bifurcata (Ulrich and Bassler)
Neoprioniodus mutabilis (Branson and Mehl)
Palmatodella delicatula Ulrich and Bassler
Palmatolepis glabra Ulrich and Bassler
P. perlobata Ulrich and Bassler
P. subperlobata Branson and Mehl

Shumla Siltstone Member

Clarke (1903, p. 25) assigned the name *Shumla* to the beds exposed at Shumla, N. Y. This member is exposed along Canadaway Creek, as are all the other members of the Canadaway Formation described in this paper. Microscopic study indicates that the Shumla is a siltstone, rather than a sandstone as first described by Clarke. It is underlain by the Westfield Shale and overlain by the Northeast Shale Member.

The Shumla has been traced from the Lake Erie shore about a half mile east of the New York-Pennsylvania State line, eastward to the eastern edge of the Cherry Creek quadrangle, about a mile north of Perrysburg. The base of the Shumla can be used as a key horizon in the Westfield, Dunkirk, and Cherry Creek quadrangles, serving as an aid in locating minor structural features.

Light gray quartzose siltstone, sometimes micaceous, occurs in the lower part of the Shumla with interbedded gray shales increasing upward. The contact between the Shumla and the overlying Northeast is transitional, and is placed where shale first predominates. The thickness of the unit varies from about 2 feet, near the New York-Pennsylvania line, to about 35 feet, near the Dunkirk-Cherry Creek quadrangle boundary.

Shumla exposures are quite numerous, occurring along lake cliffs, in stream valleys, and along road cuts. The relatively resistant siltstones sometimes act as a cap rock for small falls or rapids formed by erosion of the softer underlying Westfield Shale. Some good exposures of the Shumla occur in several stream valleys near the Lake Erie shore in the town of Ripley, along Chautauqua Creek immediately south of the United States Highway 20 bridge in the village of Westfield, along an unnamed stream about a mile southeast of Portland in the Dunkirk quadrangle, in a road cut 1.5 miles south of Lamberton, and in the valley of Canadaway Creek at Shumla, N. Y. Other good exposures include Tupper Creek and other Walnut Creek tributaries at elevations of 1,100 to 1,200 feet, a road cut close to Walnut Creek about 3 miles southwest of Forestville, along tributaries to Silver Creek 1 mile and 1.5 miles northwest of Nashville, and in the valley of Big Indian Creek 2.5 miles northwest of Perrysburg. Eastward from the latter locality, the gray siltstones acquire an increasing percentage of interbedded medium gray shales.

In the Cattaraugus quadrangle, east of the Cherry Creek quadrangle, strata equivalent to the Shumla appear almost entirely as medium gray shale, similar in lithology to the underlying and overlying Westfield and Northeast Members of the Canadaway Formation. This suggests that the Shumla, as well as the Laona, may represent off-shore bars or elongate extensions of the Catskill Delta, which trended roughly in a north-south direction through the region described in this report.

Shumla strata are often barren, although the possible plant *Taonurus* (?) sp. has been found along Canadaway Creek at the type locality. Hass (1958, p. 767) reports the following conodonts from the type locality:

Ancyrognathus bifurcata (Ulrich and Bassler)

Neoprioniodus mutabilis (Branson and Mehl)
Palmatolepis glabra Ulrich and Bassler
P. perlobata Ulrich and Bassler
P. subperlobata Branson and Mehl
Polygnathus semicostata Branson and Mehl

Northeast Shale Member

The Northeast Shale was named by Chadwick (1923, p. 69) for about 400 feet of medium gray shale with some interbedded light gray siltstone between the Shumla Siltstone and the overlying "Volusia" Shale. Chadwick (1924, p. 153) stated that the fossiliferous "Volusia" Shale overlies barren "Girard" Shale along Chautauqua Creek (Westfield quadrangle). Tesmer (1955, pp. 14-16) assigned the "Volusia" Shale with *Pugnoides duplicatus* to the Dexterville Member of the Chadakoin Formation, and incorporated the barren "Girard" Shale in the upper portion of the Northeast Shale. Thus, the Northeast Shale includes those strata between the Shumla Siltstone and the overlying Dexterville Siltstone.

The type locality for the Northeast Shale is in Northeast Township, Erie County, Pa., in the Northeast quadrangle. Although no exposure has been designated as the type section, excellent outcrops of the Northeast occur in the valleys of Sixteenmile and Twentymile Creeks. Most of the Northeast Shale beds contain few fossils, but the correlatives of this unit carry an extensive fauna east of the described area.

The thickness of the Northeast Shale varies from 600 feet at the type locality to 400 feet in the western part of the Cherry Creek quadrangle. This is only an estimate, for very few continuous exposures exist, due to the high percentage of relatively soft shales. Within the described area, a nearly complete exposure of Northeast Shale occurs along Chautauqua Creek between Westfield Village and the southern edge of the Westfield quadrangle. Another exposure is found along Canadaway Creek, between Shumla in the Dunkirk quadrangle and Griswold in the Cherry Creek quadrangle.

The lower 100 to 150 feet of the Northeast consists of medium gray shales with some interbedded light gray siltstone in layers a fraction of an inch to about 4 inches thick. These beds are usually quite barren, although the following were collected about 110 feet above the base of the Northeast, along a tributary to Walnut Creek, 1.5 miles south of Forestville in the Cherry Creek quadrangle:

BRACHIOPODS

Ambocoelia gregaria Hall
Chonetes scitulus Hall
Thiemella tenuilineata (Hall)

PELECYPOD

Palaeoneilo cf. *constricata* (Conrad)

CRINOIDS

Columnals
Mollusk of uncertain position
Hyolithes (?) sp.

None of these fossils is a good horizon marker. This small fauna seems to show relationships to both the fauna of the older Gowanda Member of the Canadaway Formation and to younger units.

The middle 200 to 250 feet of the Northeast are seen in the valleys of Chautauqua and Canadaway Creeks, where these strata commonly form steep cliffs. This part is concealed within the limits of the Cherry Creek quadrangle. The beds consist largely of medium gray shales, with only a few thin, light gray, interbedded siltstones. Some of the layers are calcareous in the Westfield quadrangle, and show well-developed cone-in-cone structure. The middle beds usually are barren.

The upper part of the Northeast Shale, about 150 to 200 feet thick, may be seen at many localities. In the Westfield quadrangle, the upper Northeast is represented by light to medium gray, sometimes calcareous, shale containing a few thin light gray siltstones. As these strata are traced eastward through the Dunkirk quadrangle, the calcareous nature is lost, and the number and thickness of interbedded siltstone increases. In the southwestern part of the Cherry Creek quadrangle, the upper Northeast consists of medium gray shale with some gray siltstones up to 4 inches thick.

An east-west environmental change is thus obvious in the upper Northeast. From west to east, calcareous shales with a few thin siltstones grade into noncalcareous shales with thicker siltstones.

In the Westfield and Dunkirk quadrangles, upper Northeast strata usually are barren. Eastward within the Cherry Creek quadrangle, these beds become increasingly fossiliferous. Along a small tributary to the North Branch of Conewango Creek, about a mile southwest of Wango in the town of Villenova, the following were noted:

BRACHIOPODS

Ambocoeila gregaria Hall
Camarotoechia contracta (Hall)
Chonetes scitulus Hall
Lingula cf. *melie* Hall
Thiemella cf. *tenuilineata* (Hall)

BRYOZOANS

Numerous forms

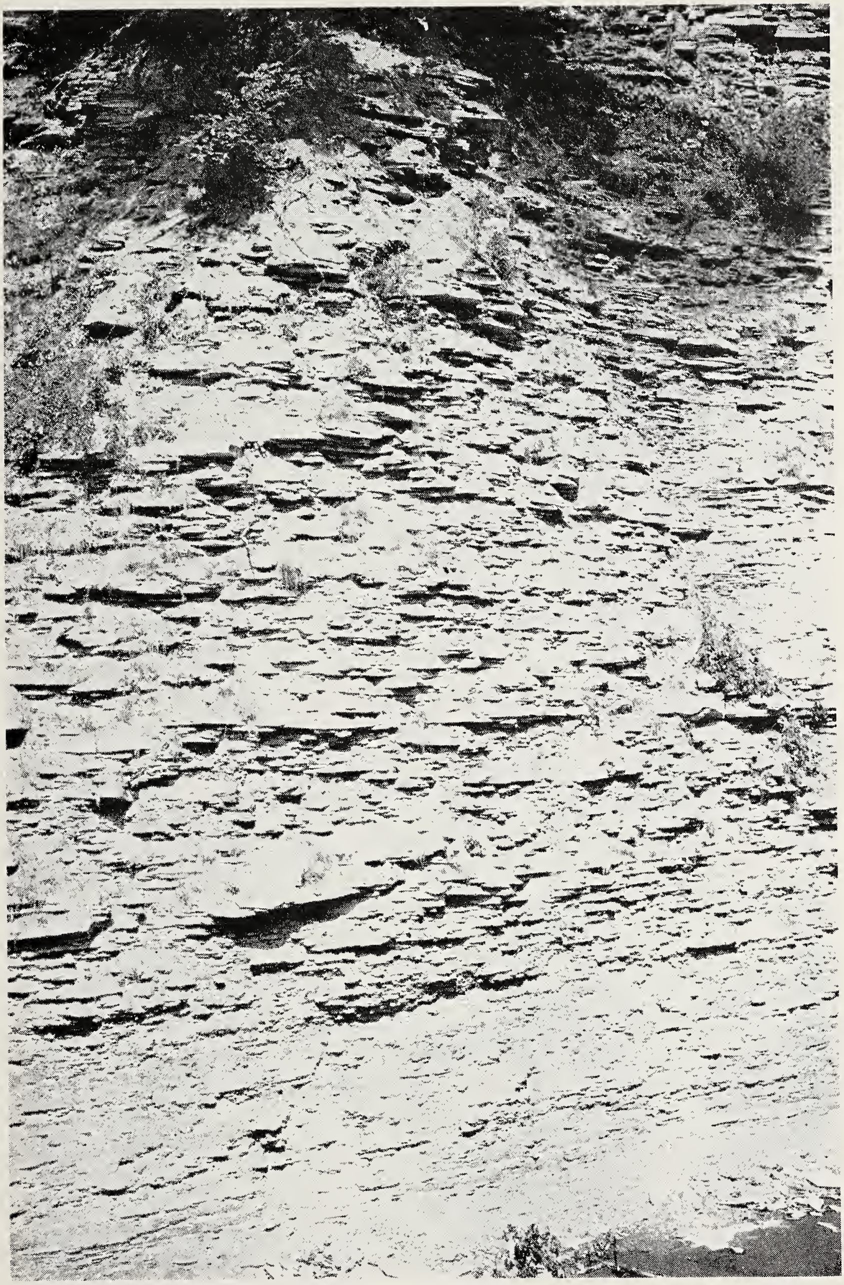


FIGURE 11. Dexterville Siltstone along Twentymile Creek in Ripley Township, Clymer quadrangle, gray siltstones with some interbedded gray shales (locality 253) *Photograph by L. V. Rickard*

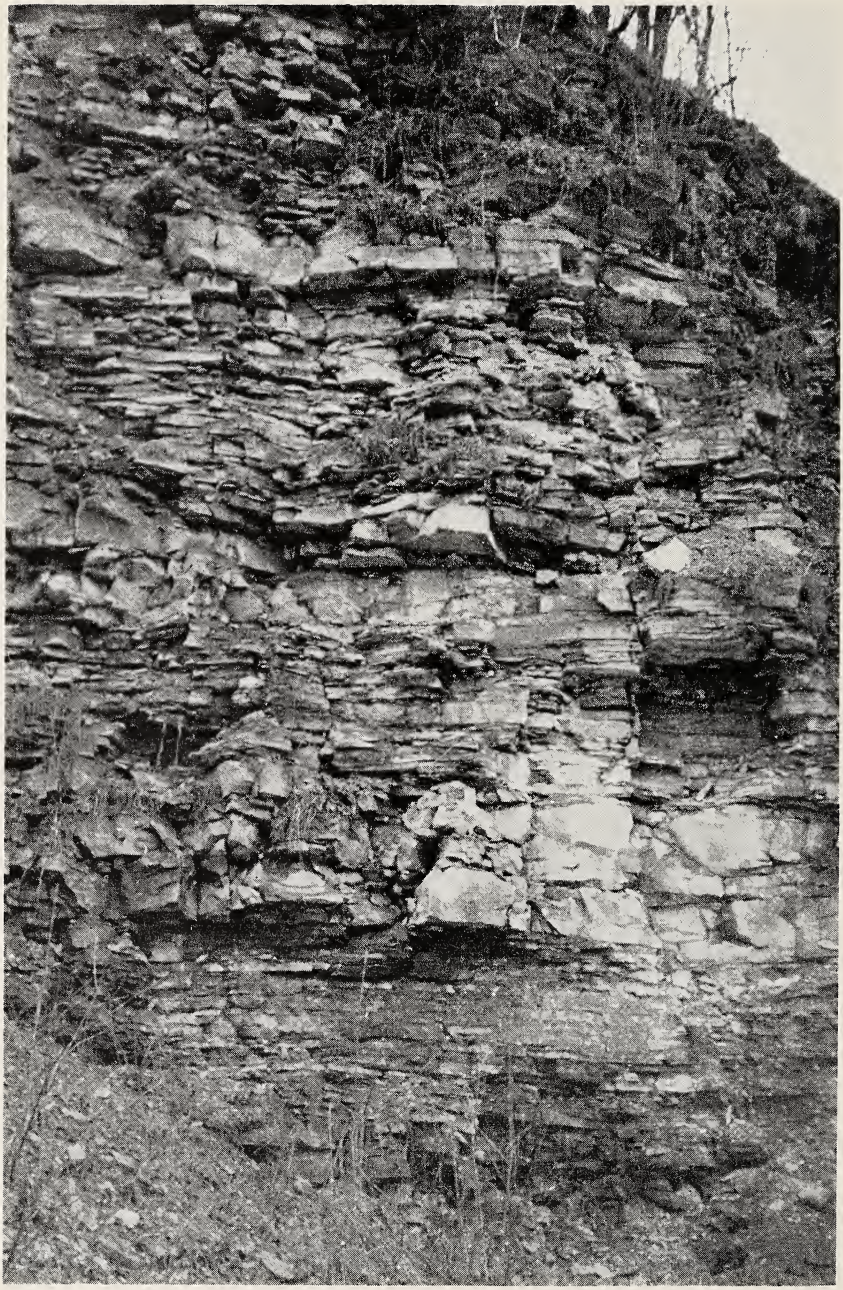


Figure 12. Dexterville Siltstone in a road cut 2 miles west of the village of Cherry Creek

In Cherry Creek Township, upper Northeast shale and siltstone beds contain the following:

CONIFEROPHYTA

Callixylon cf. *newberryi* Elkins and Wieland

BRYOZOANS

Numerous forms

BRACHIOPODS

Ambocoelia gregaria Hall
Camarotoechia contracta (Hall)
Chonetes scitulus Hall
Cyrtospirifer cf. *nucalis* Greiner
Strophalosia hystricula (Hall)
Thiemella cf. *tenuilineata* (Hall)

PELECYPODS

Grammysia sp.
Leptodesma sociale Hall

CRINOIDS

Columnals

CHADAKOIN FORMATION

The Chadakoin beds, here called the Chadakoin Formation, were originally named by Chadwick (1923, p. 69) to include a succession of interbedded gray shale and siltstone strata exposed along the Chadakoin River, in the city of Jamestown. Harris (1891, pp. 164-168) mentioned local conglomerate beds at Cherry Creek, which may be of Chadakoin age.

Caster (1934, p. 63) divided the Chadakoin Formation into the Lillibridge, Dexterville, and Ellicott Members, in ascending order. Tesmer (1955, p. 14) abandoned the "Lillibridge" as this unit appears to be lithologically indistinct. Cooper, *et al.* (1942, p. 1788), considered the Haymaker beds (Olean quadrangle) of Chadwick (1934, p. 12) as the youngest member of the Chadakoin, but the stratigraphic position and value of this unit remain uncertain. The Haymaker is not recognized in the described area. Tesmer (1955, p. 14) assigned the "Volusia" Shale of Chadwick (1923, p. 69) with *Pugnoides duplicatus* to the Dexterville Member of the Chadakoin Formation.

In the Dexterville, siltstone beds predominate, whereas the Ellicott Member contains a higher percentage of shale. *Pugnoides duplicatus* appears to be confined to the Dexterville. The upper limit of the Chadakoin is usually marked by the appearance of Cattaraugus Conglomerate with the accompanying pelecypod *Ptychopteria.* The total thickness of

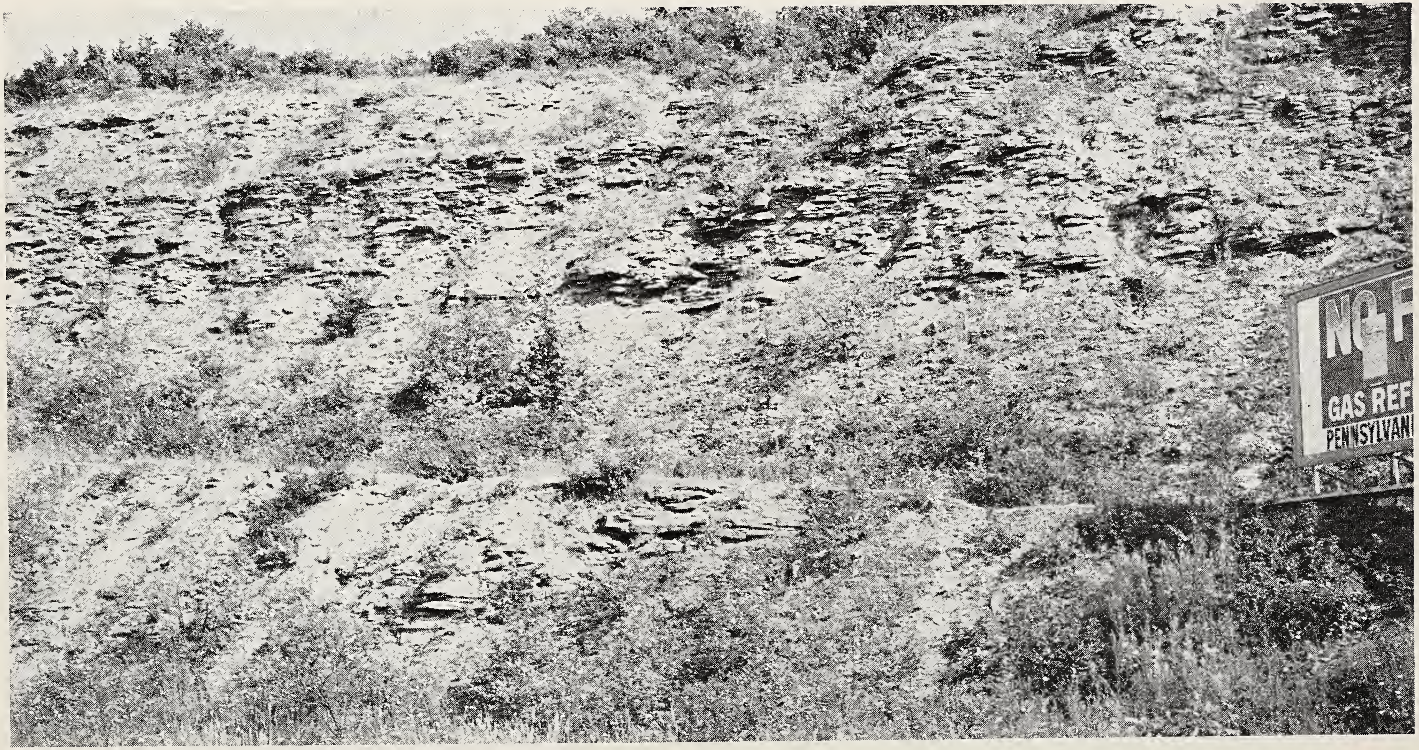


FIGURE 13. Chadakoin type locality along Chadakoin River in Jamestown, interbedded gray siltstones and shales of the Dexterville and Ellicott Members (locality 296) *Photograph by L. V. Rickard*

the Chadakoin averages about 250 feet, of which the lower 100 feet are assigned to the Dexterville Member and the remaining 150 feet to the overlying Ellicott Member.

Dexterville Member

The name *Dexterville* was proposed by Caster (1934, p. 63) for gray siltstone and some interbedded shale exposed in quarries in the eastern part of the city of Jamestown, a section formerly known as Dexterville. The zone of *Pugnoides duplicatus* is approximately equivalent to the Dexterville. This brachiopod is most often associated with thin micaceous siltstone beds.

This member has been traced from Twentymile Creek, in the town of Ripley in the Clymer quadrangle, eastward to Battle Creek, near Randolph in the Jamestown quadrangle. The presence of the index fossil *Pugnoides duplicatus* makes the Dexterville the most easily recognized unit between the base of the Shumla Siltstone and the base of the Panama Conglomerate.

Within the area, the member consists predominantly of light gray siltstone layers up to 1 foot thick with some interbedded medium gray shale. In the western part of the Westfield quadrangle, the Dexterville is about 40 feet thick, increasing to about 120 feet in the Dunkirk and Jamestown quadrangles. The Dexterville thins rapidly to the east and appears to pinch out east of the Cherry Creek quadrangle.

Dexterville exposures are too numerous to list, but a few of the best localities will be mentioned. On Twentymile Creek in the Clymer quadrangle, Dexterville strata occur about 1,140 to 1,200 feet above sea level. Here, the following have been collected:

BRACHIOPODS

Pugnoides duplicatus (Hall)
Camarotoechia contracta (Hall)
Cyrtospirifer cf. *nucalis* Greiner
Productella sp.
Strophalosia hystricula (Hall)

PELECYPOD

Mytilarca (?) sp.

BRYOZOANS

Numerous forms

CRINOIDS

Columnals

The next important exposure to the east is along Chautauqua Creek. In the Dunkirk quadrangle, an easily accessible exposure is in the small tributary to Bear Lake outlet, about 2 miles north of Stockton. Although the number of specimens is considerable, the 35 feet of gray shales and siltstones have yielded only three different brachiopods, *Ambocoelia gregaria, Pugnoides duplicatus,* and *Thiemella tenuilineata.*

From the Stockton exposure, the Dexterville may be followed south along both sides of Cassadaga Valley, past Sinclairville and Gerry to the type locality in Jamestown. The type section is described under the Chadakoin Formation. East of Jamestown, Dexterville outcrops follow the valleys of Conewango Creek and its tributaries past Kennedy and Randolph and northward through Ellington into Cherry Creek and Arkwright Townships. In a small tributary valley to Canadaway Creek, a half mile west of Arkwright, between 1,525 and 1,580 feet above sea level, the brachiopods *Ambocoelia gregaria, Pugnoides duplicatus,* and *Strophalosia hystricula* were collected.

The light gray Dexterville Siltstones of Leon Township have yielded an abundant fauna.

Bryozoans

Numerous forms

Brachiopods

Ambocoelia gregaria Hall
Athyris angelica Hall
Camarotoechia contracta (Hall)
Chonetes cf. *scitulus* Hall
Cyrtospirifer cf. *nucalis* Greiner
Petrocrania cf. *leonis* (Hall)
Productella cf. *lachrymosa* (Conrad)
P. cf. *speciosa* Hall
Schellwienella chemungensis (Conrad)
Strophalosia hystricula (Hall)
Thiemella tenuilineata (Hall)
T. villenovia Williams

Pelecypods

Aviculopecten cancellatus Hall
Crenipecten leon Hall
Mytilarca chemungensis (Conrad)
Palaeoneilo cf. *constricta* (Conrad)
Sanguinolites undulatus Hall
Sphenotus cf. *contractus* Hall

Gastropod

Straparolus hecale Hall

Crinoids

Columnals

Ellicott Member

The name *Ellicott* was proposed by Caster (1934, p. 66) for gray shale and some interbedded siltstone between the Dexterville Siltstone and overlying Panama Conglomerate. The present writer considers the upper limit of the Ellicott marked by the lowest local conglomerate member of the Cattaraugus Formation, often the Panama Conglomerate. Cooper, *et al.* (1942, p. 1788), suggested the correlation of the Tanners Hill red beds of the Warren quadrangle (see Carll, 1883, p. 297) with the Ellicott Shale. The present writer places the Tanners Hill strata, absent within the described area, in the Cattaraugus Formation.

The Ellicott type locality is in Ellicott Township in the Chautauqua quadrangle, along Hunt Road, between Ashville and Jamestown. *Pugnoides duplicatus,* an index to the Dexterville, does not extend upward into the Ellicott.

The member averages about 150 feet within the described area. Although often concealed by mantle, the Ellicott underlies a substantial portion of all six quadrangles. The unit has been observed from exposures along Twentymile Creek near the northwest corner of the Clymer quadrangle to outcrops in Randolph Township near the eastern edge of the Jamestown quadrangle.

Complete sections of the Ellicott Member are seldom exposed. One of the few nearly continuous sections occurs along a small stream near the northeast corner of Charlotte Township, in the Cherry Creek quadrangle.

Along Twentymile Creek in Ripley Township in the Clymer quadrangle, Ellicott exposures occur between 1,200 and 1,380 feet. Here, the following were noted:

BRACHIOPODS

Camarotoechia contracta (Hall)
Cyrtospirifer sp.
Productella cf. *onusta* Hall
Leiorhynchus (?) sp.

PELECYPODS

Various forms

BRYOZOANS

Numerous forms

CRINOIDS

Columnals

A typical Ellicott exposure in the Dunkirk quadrangle occurs in a small tributary to the Big Inlet of Chautauqua Lake in Chautauqua Township, about 3 miles north of Hartfield, which yielded:

BRACHIOPODS

Camarotoechia contracta (Hall)
Cyrtospirifer sp.
Productella cf. *lachrymosa* (Conrad)

PELECYPOD

Mytilarca chemungensis (Conrad)

BRYOZOANS

Numerous forms

CRINOIDS

Columnals

An excellent locality for collecting Ellicott fossils is in Busti Township in the Chautauqua quadrangle, about a mile southwest of the village of Lakewood, along an Erie Railroad cut, where the following were observed:

BRACHIOPODS

Camarotoechia contracta (Hall)
Cyrtospirifer sp.
Productella sp.

PELECYPODS

Leptodesma sp.
Mytilarca chemungensis (Conrad)
Numerous other forms

CRINOIDS

Columnals

In Cherry Creek Township, a road cut 2.5 miles west of the village of Cherry Creek yielded the following:

BRACHIOPODS

Camarotoechia contracta (Hall)
Cyrtospirifer sp.

PELECYPODS

Leptodesma cf. *potens* Hall
Pteronites profundus Hall

BRYOZOANS

Numerous forms

CRINOIDS

Columnals

Hass (1958, p. 767) reports the following conodonts from the Ellicott Shale of Jamestown and vicinity:

Neoprioniodus mutabilis (Branson and Mehl)

Palmatolepis distorta Branson and Mehl
Polygnathus semicostata Branson and Mehl
Polylophodonta confluens (Ulrich and Bassler)

The Ellicott fauna shows a transition from the base to the top. *Ambocoelia gregaria* and *Strophalosia hystricula,* quite common in the Dexterville and lower Ellicott, become rare or absent in younger strata. These forms are supplanted in part by pelecypods, particularly *Leptodesma potens,* which first appears locally in the Ellicott Member.

CONEWANGO GROUP

The name *Conewango* was introduced by Butts (1908, p. 191) for a formation equivalent to the Cattaraugus and Oswayo Formations of the Olean quadrangle. Caster (1934, pp. 62-63) considered the Conewango a series composed of several subdivisions, the names of which were listed on the Devonian correlation chart (Cooper, *et al.*, 1942, p. 1786). Tesmer (1955, p. 8) suggested use of the name *Conewango* as a group, consisting of three formations: Cattaraugus, Oswayo, and Knapp. Recent paleontological studies by Holland (1959, p. 1619) indicate that Knapp brachiopod species show a closer relationship to the Mississippian than to the Upper Devonian. Therefore, the Conewango Group is now limited to the Cattaraugus and Oswayo Formations.

The type locality for the Conewango Group is along Conewango Creek in the Warren, Pa., quadrangle. Here, interbedded shales, siltstones, sandstones, and conglomerates are exposed. The Oswayo Formation, characterized by its index fossil, *Camarotoechia allegania,* is not present in the described area, and the Conewango is represented by only the Cattaraugus Formation, consisting of about 650 feet of strata.

CATTARAUGUS FORMATION

Clarke (1902, p. 525) introduced the name *Cattaraugus* for red and gray shales interbedded with flaggy siltstones between the Wolf Creek and Salamanca Conglomerates. Glenn (1903, pp. 971-978) expanded the Cattaraugus to include not only the shales and siltstones but also the Wolf Creek, Salamanca, and Killbuck Conglomerates of the Salamanca-Olean region. Caster (1934, table opposite p. 63) recognized the following sequence in northwestern Pennsylvania: Panama Conglomerate, Amity Shale (including Dutchmans Conglomerate), Salamanca (two conglomerate units with intervening shale), Saegerstown Shale (including Tunangwant Conglomerate).

It has been apparent to all workers since Glenn (1903, pp. 971-978) that the term *Cattaraugus* denotes a stratigraphic succession consisting

PLATE 4

Cattaraugus Fossils

A. *Ptychopteria* cf. *galene* Hall, left valve. Cherry Creek Township. Locality 721 N.Y.S.M. 11456.

B. *Ptychopteria* cf. *sao* Hall, left valve. Cherry Creek Township. Locality 721 N.Y.S.M. 11457.

C. *Camarotoechia* sp. Charlotte Township. Locality 731 N.Y.S.M. 11458.

D. *Cyrtospirifer* cf. *tionesta* Greiner, brachial valve. Cherry Creek Township. Locality 747 N.Y.S.M. 11459.

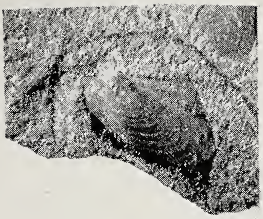
E. *Productella* cf. *hirsuta* Hall. Charlotte Township. Locality 731 N.Y.S.M. 11460.

F. *Productella* cf. *onusta* Hall. Charlotte Township. Locality 731 N.Y.S.M. 11461.

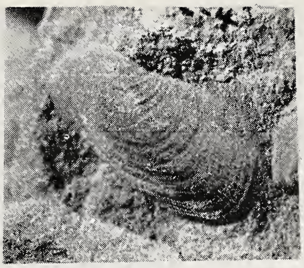
G. *Leptodesma* cf. *sociale* Hall. Cherry Creek Township. Locality 721 N.Y.S.M. 11462.

H. *Ptychopteria* cf. *sinuosa* Hall, left valve. Cherry Creek Township. Locality 721 N.Y.S.M. 11463.

(All figures are natural size.)



A



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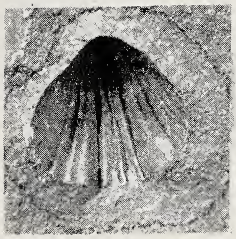

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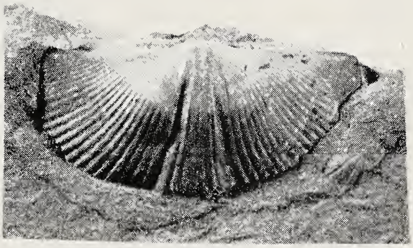

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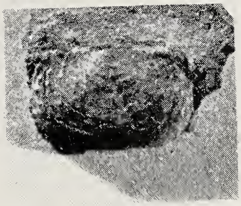

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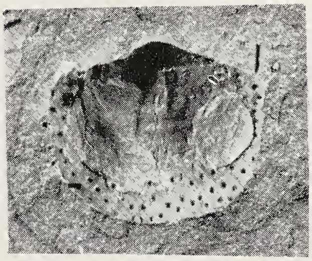
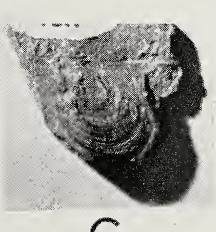
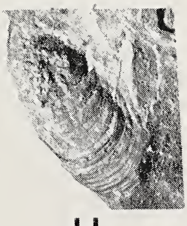


F



G



H

primarily of conglomerates with some interbedded shales and siltstones. In this paper, the Cattaraugus Formation is defined as including 650 feet of strata lying between the Chadakoin and Oswayo or Knapp Formations. Tesmer (1958, p. 1651) indicated a proposed sequence of Cattaraugus members and suggested possible correlation of certain of the conglomerates found in southwestern New York and northwestern Pennsylvania. This revised sequence, if accepted, would invalidate Amity and Saegerstown as defined by Chadwick (1925, pp. 457-458), and these units are not used here. As the sequence and correlation of Cattaraugus Members is still somewhat uncertain, the Cattaraugus Formation is considered as an undifferentiated unit, except for the Panama and Pope Hollow Conglomerate Members whose type localities occur within the described area.

Exposures of Cattaraugus Conglomerates are scattered throughout the Clymer, Chautauqua, Jamestown, and southern part of the Cherry Creek quadrangles. Exposures include Herrick Creek Valley, along a small creek a mile south of Clymer Hill, and a small abandoned quarry about a half mile east of North Clymer. In the Chautauqua quadrangle, the best exposures of conglomerate occur near the village of Panama. Conglomerate beds are common along numerous stream cuts in Charlotte, Cherry Creek, Gerry, and Ellington Townships above elevations of 1,700 feet, and in Carroll and South Valley Townships above 1,450 feet.

Cattaraugus shales and siltstones occur throughout the formation and are frequently exposed. Light gray siltstone beds from 1 to 4 inches thick are commonly interbedded with some gray shale. Red shales present on a hill a half mile west of Kiantone, Jamestown quadrangle, at elevations of 1,570 to 1,610 feet, are believed to be the oldest significant red beds within the area.

Good exposures of the upper portion of the Cattaraugus Formation are quite limited. However, along the road which crosses the divide between Frews Run and the north branch of Sawmill Run, in Carroll Township near the Chautauqua-Cattaraugus County line, gray micaceous siltstones with *Cyrtospirifer tionesta* and some crinoid stems are exposed intermittently between elevations of 1,950 and 2,050 feet.

In Cherry Creek Township, at about 1,920 feet, buff coarse sandstone, containing the pelecypods *Ptychopteria* cf. *galene* and *P.* cf. *sao,* is exposed. Plant fragments assigned to the genus *Callixylon, Camarotoechia* cf. *contracta,* and "*Orthoceras*"-type cephalopods were collected from conglomerates exposed along the road which crosses the southern edge of South Valley Township, Jamestown quadrangle, at about 1,900 feet.

Gray shale and siltstone beds exposed in a small tributary valley to Little Brokenstraw Creek in Harmony Township in the Chautauqua quadrangle yield the following:

BRYOZOANS

Numerous forms

BRACHIOPODS

Camarotoechia contracta (Hall)
Cyrtospirifer cf. *tionesta* Greiner

PELECYPODS

Edmondia sp.
Mytilarca cf. *gibbosa* Hall
Palaeoneilo sp.
Ptychopteria spp.

Fossiliferous gray shale and siltstone beds occur in the southwestern part of the Cherry Creek quadrangle. The following list of forms was obtained from two localities about 4.5 miles west of the village of Cherry Creek.

BRACHIOPODS

Ambocoelia gregaria Hall
Camarotoechia contracta (Hall)
C. sappho (Hall)
Chonetes scitulus Hall
Cyrtospirifer cf. *tionesta* Greiner
Productella hirsuta Hall
P. onusta Hall

PELECYPODS

Leptodesma sociale Hall
Palaeanatina cf. *angusta* Hall
Ptychopteria cf. *sinuosa* Hall

BRYOZOANS

Numerous forms

The pelecypods *Mytilops*, *Pararca*, and *Ptychopteria* first appear in the Cattaraugus. See Chadwick (1935b, pp. 328-333). *Mytilops* and *Ptychopteria* may be confined to this unit. *Leiopteria* and *Lyriopecten* have not been found in rocks younger than Cattaraugus. Cattaraugus fossils are illustrated in plate 4.

Panama Conglomerate Member

Carll (1880, p. 58) proposed the name *Panama* for 69 feet of conglomerate and sandstone exposed in the village of Panama, N. Y.,

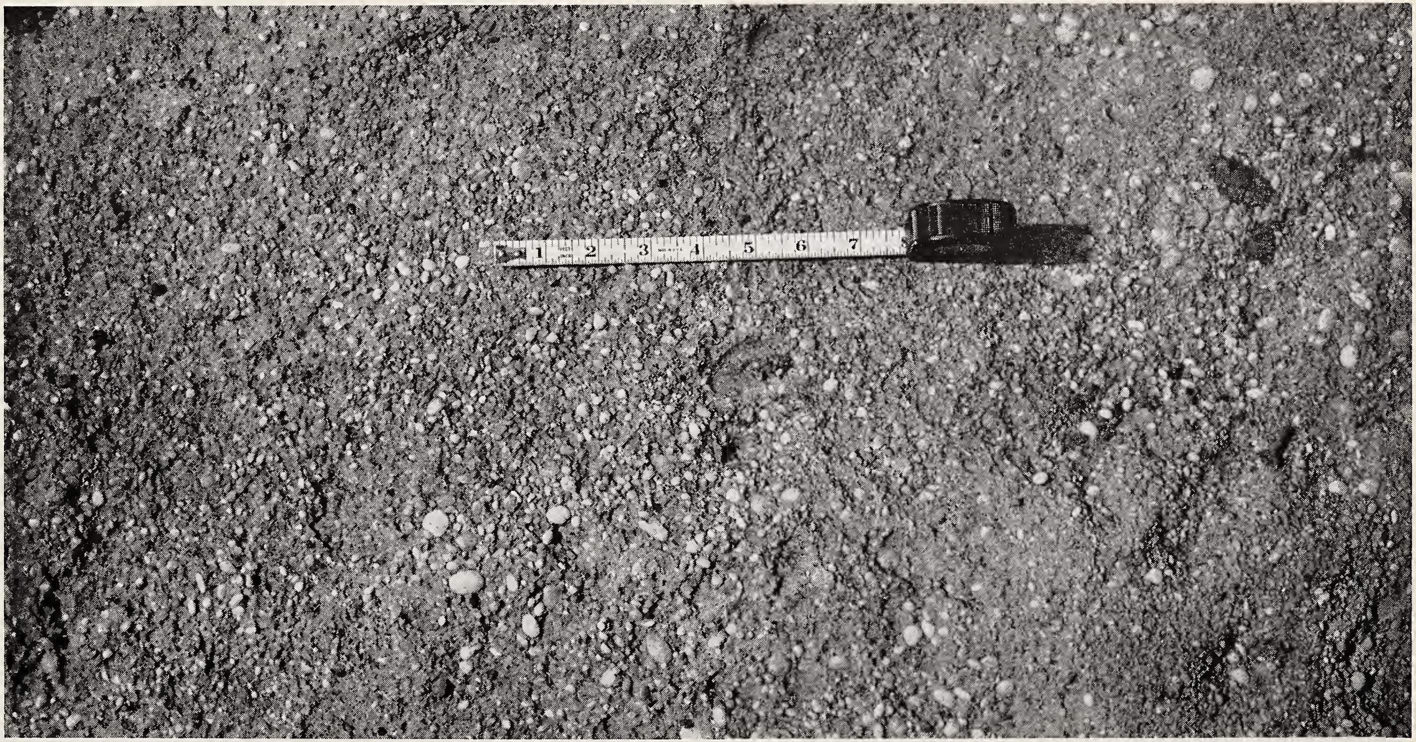


FIGURE 14. Panama Conglomerate at Panama Rocks. Type locality, Harmony Township, Chautauqua County, rounded pebbles of milky quartz (locality 414) *Photograph by L. V. Rickard*

Chautauqua quadrangle. Although the average thickness is between 20 and 30 feet, it varies within relatively short distances and may reach 100 feet or more.

Within the described area, the Panama generally consists of interbedded buff-colored, friable, coarse sandstone and conglomerate with milky quartz or occasional jasper pebbles, usually less than an inch in diameter, imbedded in a dark gray quartzitic matrix. Locally, there are some interbedded gray siltstone and light gray shale.

Pope Hollow Conglomerate Member

The Pope Hollow Conglomerate was named by Carll (1883, p. 180). The type locality occurs in the southeast corner of the Jamestown quadrangle, on a small tributary to Cass Run, along the boundary between Chautauqua and Cattaraugus Counties. Several conglomerates may be observed in Pope Hollow Valley, but the Pope Hollow Conglomerate is the unit that is exposed from about 1,895 to 1,910 feet. The Pope Hollow is similar in appearance to the Panama.

Lower Mississippian (Kinderhookian Series)

The name *Kinderhook Group* was proposed by Meek and Worthen (1861, p. 288) for rock exposures at Kinderhook, Ill. Weller, *et al.* (1946, p. 188), regard the Kinderhookian as the basal Mississippian Series.

KNAPP FORMATION

The name *Knapp* was originally assigned by Glenn (1903, pp. 980-982) to two conglomerate beds with an intervening shale lying between the Oswayo Shale and the Olean Conglomerate, at Knapp Creek in the Salamanca quadrangle. The age of the Knapp has remained uncertain for many years. Cooper, *et al.* (1942, p. 1788), listed the Knapp as Devonian or Mississippian, while Weller, *et al.* (1948, p. 188), considered the formation as basal Mississippian.

Recent paleontological studies by Holland (1959, p. 1619) indicate that Knapp brachiopod species show a closer relationship to the Mississippian than to the brachiopods in the underlying Conewango Group.

The only Knapp exposures within the area occur on the highest hills of the Jamestown quadrangle, in South Valley Township, where between 10 and 40 feet of strata are found at about 2,100 feet. No fossils were observed.

Correlations

The formations proposed in this paper may readily be distinguished in the field. Many of the members, however, are relatively localized, and correlation of these lesser stratigraphic units on a regional basis is more difficult.

Tesmer (1955, p. 10) presented detailed correlations of the members of the Arkwright Group. A proposed correlation of conglomerates in southwestern New York and northwestern Pennsylvania has been suggested by Tesmer (1958, p. 1651).

Table 2.

Suggested Correlation of Stratigraphic Units

Chautauqua County	Genesee Valley
Lower Mississippian (Kinderhookian Series)	
Knapp Formation	Knapp Formation
Upper Devonian (Chautauquan Series)	
Conewango Group	Conewango Group
(missing)	Oswayo Formation (?)
Cattaraugus Formation (includes Panama, Pope Hollow)	Cattaraugus Formation (includes Wolf Creek, Salamanca)
Arkwright Group	Arkwright Group
Chadakoin Formation	Chadakoin Formation
	Whitesville Member
Ellicott Member	Hinsdale Member
Dexterville Member	Wellsville Member
Canadaway Formation	Canadaway Formation
	Cuba Member
Northeast Member	Machias Member
Shumla Member	
Westfield Member	Rushford Member
Laona Member	
	Caneadea Member
Gowanda Member	Hume Member
	Canaseraga Member
South Wales Member	South Wales Member
Dunkirk Member	Dunkirk Member
Seneca Group	Seneca Group
Java Formation	Java Formation
Hanover Shale	Wiscoy Sandstone
Pipe Creek Shale	Pipe Creek Shale
West Falls Formation	West Falls Formation
	Nunda Sandstone
Angola Shale	West Hill Siltstone
	Gardeau Shale

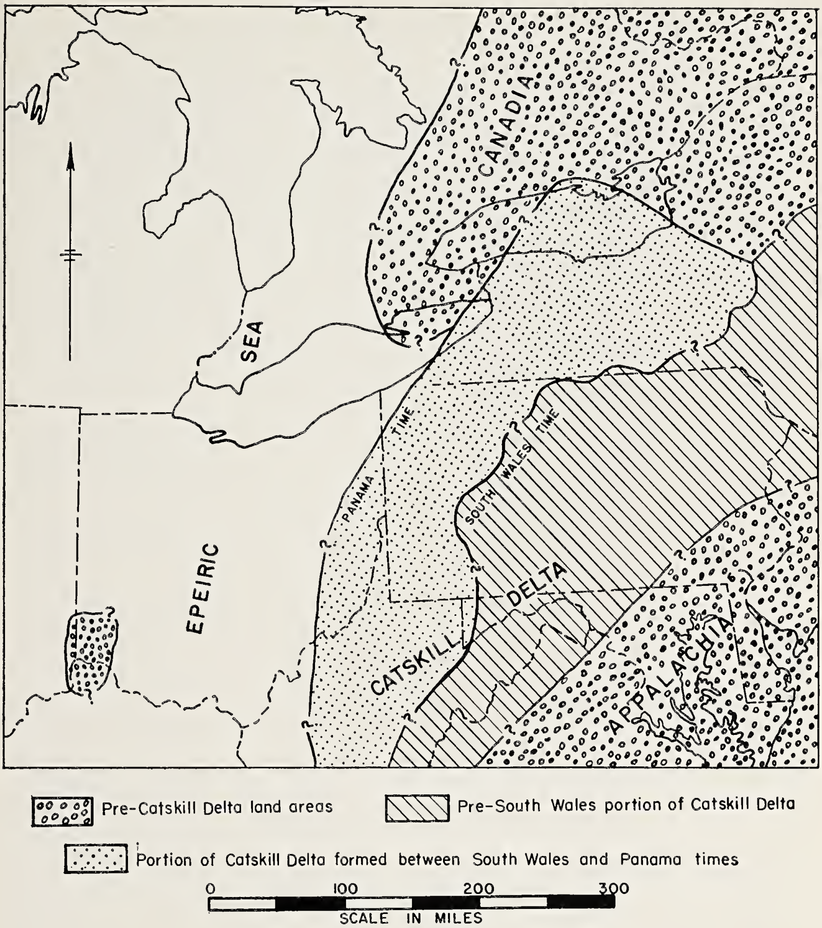

CANADIA
SEA
EPEIRIC
PANAMA TIME
SOUTH WALES TIME
CATSKILL DELTA
APPALACHIA
Pre-Catskill Delta land areas
Pre-South Wales portion of Catskill Delta
Portion of Catskill Delta formed between South Wales and Panama times
0
100
200
300
SCALE IN MILES

FIGURE 15. Paleogeographic map of eastern Great Lakes region

Although the terminology may vary with different authors, the concept of magnafacies and parvafacies proposed by Caster (1934, pp. 19-36) has value in interpreting the geologic history of the various deltaic deposits exposed within the region. Magnafacies represent a particular type of lithology which is time-transgressive under deltaic conditions, whereas that portion of a magnafacies which lies within an arbitrary unit of time is known as a parvafacies. Caster (1934, p. 21) grouped parvafacies of the same age as stages. These stages are usually bounded by lithologic changes which are only approximately synchronous.

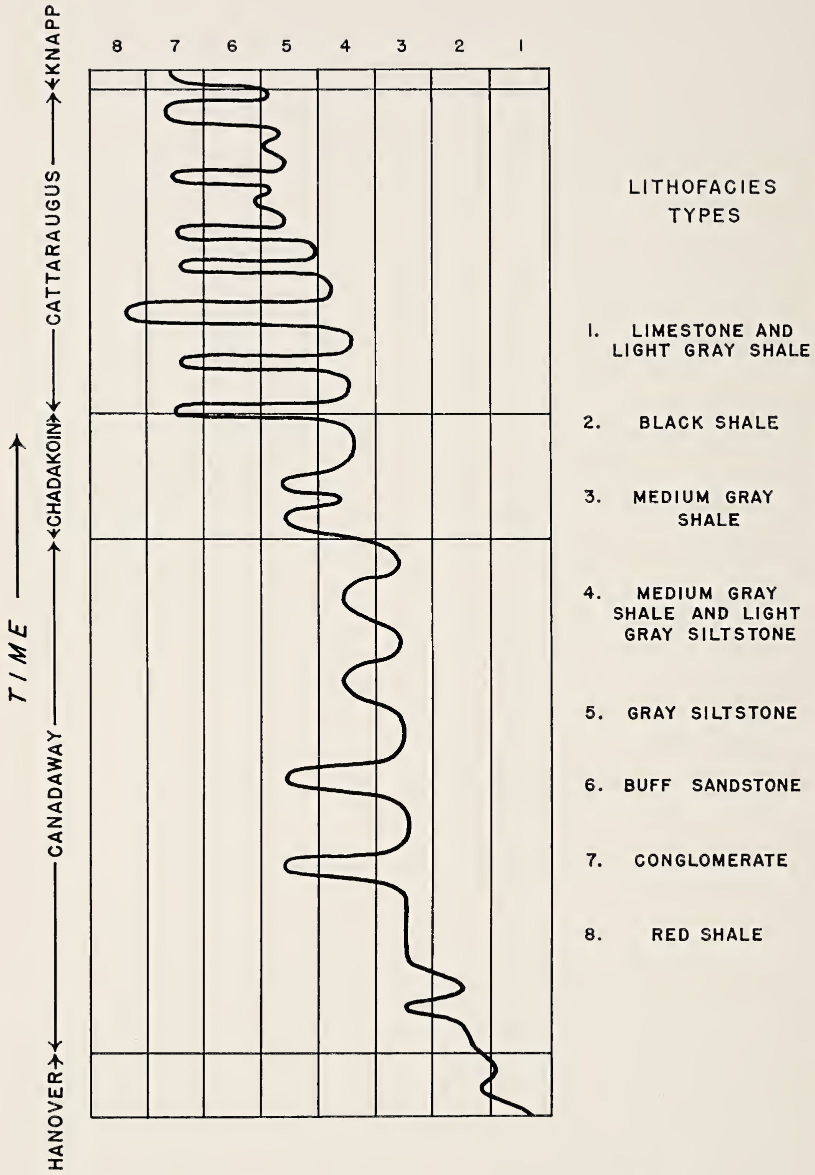


FIGURE 16. Variation of sedimentation with time

Paleogeography and Sedimentation

All bedrock exposed within the area, except possibly the Knapp Conglomerate, is associated with an ancient delta formed in eastern New York and Pennsylvania, which slowly spread westward. Information concerning the Catskill Delta has been gathered by several workers. Pepper and de Witt (1950, 1951) stated that the shoreline gradually approached from the east and southeast (figures 15 and 16). During South Wales time, the shoreline passed through central New York and Pennsylvania. By Panama time, it had migrated to or very near the described area, as Panama and younger conglomerates formed in very shallow water or possibly on land.

The Catskill Delta probably consisted of several coalescing deltas, a factor which might explain some of the apparent lensing of the Laona, Shumla, and Rushford Siltstones. In the Genesee Valley area, the local Rushford Siltstone has a lithology and fauna similar to the Laona. Similar position in the stratigraphic sequence is an additional indication that the two units may be contemporaneous. Surface exposures of the Laona and Rushford Siltstones are separated by a region containing medium gray shale, and thus it has not been possible to determine the exact stratigraphic relationship between the two units. Well logs seem to indicate that both the Laona and Rushford thicken and coarsen to the south and southeast, implying that the source of the sediments lay in that direction. Additional subsurface stratigraphic studies might prove that the Laona and Rushford Siltstones merge to the south, thus indicating that each unit represents a separate arm of the delta which extended northward and northwestward from Pennsylvania into New York during Laona time.

The Catskill Delta expanded westward, gradually filling the arm of an epeiric sea which occupied western New York and western Pennsylvania. The main body of the sea lay farther to the west, partly in Ohio. Pebbles and cross-bedded sand usually accumulated close to the shoreline, in an environment affected by wave action. At a greater distance from the land, but still in relatively shallow water, ripple-marked silt was deposited. Medium gray to grayish-black muds accumulated in a deeper water environment, while calcareous muds are associated with the relatively clear waters of Ohio, at a considerable distance from the shoreline.

Repetition of lithofacies may be observed in the exposed strata of the area (figure 16). In an ideal sequence from sea to shore, limestone would be followed by black shale, medium gray shale, light gray siltstone, buff sandstone, conglomerate, and finally by nonmarine red shale and sandstone. In the lower Canadaway, interbedded black and medium gray shales are dominant although a few thin beds of limestone and light gray siltstone are also present. In the upper Canadaway and Chadakoin, interbedded medium gray shale and light gray siltstone occur. The Cattaraugus Formation contains repeating lithofacies which range from medium gray shale to coarse sandstone and conglomerate. Nonmarine red shale occurs in only a few places in the Jamestown quadrangle, but becomes more common east of the described area.

Minor lithologic changes within members indicate only local changes in sedimentation and in the position of the strand line. A return to black shale at the base of the Dunkirk and Gowanda, the relatively sudden appearance of siltstone at the bases of the Laona and Shumla, and the deposition of conglomerates, such as the Panama and Knapp, indicate changes on a larger scale.

Sedimentary structures are common and varied in Chautauqua County. Conglomerates such as the Panama often show cross-bedding, characteristic of shallow water deposits. The siltstone and sandstone beds commonly exhibit wave ripple marks, rill marks resulting from undertow, and furrows or groove casts resulting from objects which were dragged across the unconsolidated silt or sand.

Shale beds sometimes show mud cracks and often contain concretionary beds of either a calcareous or arenaceous nature. In some of the thin limestone beds in the Northeast Shale, close to the New York-Pennsylvania line, some cone-in-cone structures have been observed. These structures are the result of solution which occurs under pressure.

Structural Geology

Surface structures within the described area are simple and homoclinal. The regional dip is generally to the south at about 20 to 50 feet per mile. As the dip is very low, the direction and magnitude of dip are changed in places by minor local structures. Only a few key horizons are present, and these are often poorly exposed. The base of the Pipe Creek, Dunkirk, Laona, Shumla, and Dexterville serve as the best horizon markers.

No major faults occur within the area, although local minor folds in incompetent beds may occasionally show faults with a displacement seldom exceeding a few inches. Chadwick (1920, p. 120) described a local fault with a throw of 25 feet and a heave of about 100 feet which he believed existed along a tributary to Walnut Creek, about a mile northwest of Nashville in the Cherry Creek quadrangle. The present writer is uncertain whether a fault or a fold is represented, as key horizons are not well represented. Some of the rock units in the area show well-developed joint sets, but none was studied in detail.

The Shumla and Laona Siltstones* often have a pronounced petroliferous odor when freshly exposed. These units sometimes serve as oil and gas reservoir rocks if they are sufficiently buried and locally permeable. However, the oil and gas fields seem more related to variations in permeability than to any structures which can be measured at the surface.

Future Investigations

The principal stratigraphic problem remaining is the distribution and relationships of the conglomerates of the Cattaraugus Formation. The writer's investigations have indicated that at least five conglomerates occur in this formation, but their precise relationships have not been satisfactorily determined because of their infrequent exposure, lack of distinctive criteria, and apparent lens-like occurrence. It is hoped that future work will permit the separation and tracing of these conglomerates, so that more precise subdivision and correlation of the Cattaraugus may be accomplished.

The author has made no attempt to investigate in detail the mineralogical and petrographic nature of the strata exposed in Chautauqua County, and these studies remain. Sedimentary structures of many different types have been observed and deserve further study. Extensive collections and thorough study of certain fossil groups, notably the brachiopods, bryozoans, and conodonts should be undertaken. The above investigations would undoubtedly advance our understanding of the sedimentary environments under which the rocks of Chautauqua County were formed.

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* These are commonly correlated with the Bradford Second and Third Sands, respectively.

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Appendix

Walnut Creek Section

From U.S.G.S. Oil and Gas Investigations Preliminary Chart 37 (Pepper and de Witt, 1950):

(Ascending order)

Angola	3′	gray shale with small calcareous concretions less than 2″ in diameter
Pipe Creek	2′	black shale
Hanover	3′	gray shale
	1′	black shale
	7′	gray shale with small calcareous concretions less than 2″ in diameter
	1′	black shale
	2′	gray shale with ellipsoidal calcareous concretions 2″-1′ in diameter
	1′	black shale
	3′	gray shale with ellipsoidal calcareous concretions 2″-1′ in diameter
	1′	black shale
	2′	gray shale with ellipsoidal calcareous concretions 2″-1′ in diameter
	3′	black shale
	2′	gray shale
	1′	black shale
	10′	gray shale with small calcareous concretions less than 2″ in diameter
	1′	black shale
	8′	concealed
	1′	black shale
	6′	gray shale
	4′	interbedded gray and black shale
	6′	gray shale
	4′	interbedded gray and black shale
	5′	gray shale
	1′	gray gnarled limestone
	6′	gray shale with small calcareous concretions less than 2″ in diameter
	3′	gray gnarled shale
	1′	black shale
	3′	gray shale with ellipsoidal calcareous concretions 2″-1′ in diameter
	6″	gray limestone
	3′	greenish-gray shale with small calcareous concretions less than 2″ in diameter
	6″	gray limestone

Hanover (*Cont.*)
5′ gray shale with small calcareous concretions less than 2″ in diameter
2′ greenish-gray shale
1′ black shale
1′ greenish-gray shale

From U.S.G.S. Oil and Gas Investigations Chart OC 45 (Pepper and de Witt, 1951):

Dunkirk
15′ black shale with ellipsoidal calcareous septaria 2″-1′ in diameter
2′ gray shale with ellipsoidal calcareous septaria more than 1′ in diameter
19′ black shale
6″ gray siltstone
2′ black shale

South Wales
7′ gray shale with ellipsoidal calcareous concretions 2″-1′ in diameter
6″ gray siltstone
3′ gray shale with small silty concretions less than 2″ in diameter
1′ black shale
3′ gray shale
6″ gray siltstone
1′ black shale
11′ gray shale with ellipsoidal calcareous concretions 2″-1′ in diameter
(boundary between Silver Creek and Cherry Creek quadrangles)
2′ black shale
1′ gray shale
2′ black shale
1′ gray shale
1′ black shale
3′ gray shale with small calcareous concretions less than 2″ in diameter
1′ black shale
3′ gray shale with small calcareous concretions less than 2″ in diameter
1′ black shale
3′ gray shale
2′ black shale
8′ gray shale
1′ black shale
15′ gray shaly siltstone
1′ gray siltstone
2′ gray shale
1′ black shale
2′ gray shale
1′ black shale
2′ gray shale

Gowanda
11′ black shale
1′ gray shale
1′ black shale

Gowanda	2′	gray shale
(*Cont.*)	1′	black shale
	2′	gray shale
	1′	black shale
	3′	gray silty shale
	2′	black shale
	5′	gray shale
	3′	black shale
	1′	gray shale
	1′	gray siltstone
	2′	gray shale
	1′	gray siltstone
	10′	concealed
	1′	black shale
	3′	gray silty shale with ellipsoidal silty concretions more than 1′ in diameter
	8′	gray shale
	6′	black shale
	3′	gray shale
	1′	gray siltstone
	6′	gray shale
	1′	gray siltstone
	18′	gray shale
	2′	gray siltstone
	11′	concealed
	11′	gray shale with ellipsoidal calcareous septaria 2″-1′ in diameter
	3′	gray silty shale with small calcareous concretions less than 2″ in diameter
	12′	gray shale with ellipsoidal calcareous concretions more than 1′ in diameter
	1′	gray siltstone
	5′	concealed
	2′	gray shale
	1′	gray siltstone
	2′	gray shale
	1′	gray siltstone
	3′	gray shale with ellipsoidal calcareous concretions 2″-1′ in diameter containing *Aulatornoceras clarkei* and pyritized algae
	3′	black shale
	28′	gray shale with ellipsoidal calcareous concretions 2″-1′ in diameter
	1′	gray siltstone
	1′	gray shale
	1′	gray siltstone
	2′	gray shale
	1′	gray siltstone

Gowanda (*Cont.*)	2′	gray shale
	14′	concealed
	4′	gray shale
	1′	black shale
	6′	gray shale
	1′	black shale
	3′	gray shale

Scott Creek Section

Sheridan Township, Dunkirk quadrangle:

(Ascending order)

Laona	8′	massive gray siltstone 4″ to 10″ thick whose surfaces exhibit excellent ripple marks
	5′	gray 4″ to 6″ siltstone
	4′	thin gray siltstone
	2′	concealed
	1′	gray siltstone
	1′	concealed
	5′	gray 1″ to 2″ siltstone
Westfield	6′	concealed
	8′	gray shale with some thin gray siltstone
	23′	fissile gray shale with a few thin gray siltstones
	8′	concealed
	16′	gray shale with some gray siltstone
	5′	interbedded gray siltstone and gray arenaceous shale
	3′	gray shale
	3′	concealed
	3′	gray shale
	18′	gray shale with some 1″ to 3″ gray siltstone
	1′	gray siltstone
	15′	gray shale with some gray siltstone
	1′	massive gray siltstone
	6′	gray shale with some gray siltstone
	9′	concealed
	19′	gray shale with some gray siltstone
	9′	concealed
	22′	interbedded gray shale and 1″ to 4″ gray siltstone
Shumla	12′	massive gray siltstone: beds average 6″ in thickness
	4′	interbedded gray shale and massive gray siltstone
	1′	calcareous concretions
	4′	gray siltstone, 1″ to 2″ thick
	6″	calcareous concretions up to 2′ in diameter
	12′	thin to massive gray siltstone

Chautauqua Creek Section

(Ascending order)

Northeast	10′	mostly gray shale with a little interbedded thin to 4″ gray siltstone
	6′	interbedded gray shale and thin to 5″ gray siltstone
	5′	mostly gray shale with only a few thin gray siltstones
	5′	mostly gray shale with a few thin to 3″ gray siltstones
	25″	massive gray siltstone bed
	10′	mostly gray shale with some thin to 2″ gray siltstone
	15′	mostly gray shale with a little thin to 2″ gray siltstone
	3′	mostly 1″ to 6″ gray siltstone
	15′	concealed
	25′	mostly gray shale with some thin to 3″ gray siltstone containing *Taonurus* sp.
	3′	mostly gray thin to 4″ siltstone
	25′	mostly gray shale with a few thin to 2″ gray siltstones
	3′	1″ to 4″ gray siltstone
	20′	gray shale with some thin to 2″ gray siltstone
	15′	gray shale with only a few thin gray siltstones
	5′	gray shale with some thin to 2″ gray siltstone
	50′	gray shale with only a very few thin gray siltstones
	14″	massive gray siltstone bed
	10′	mostly gray shale with a very few thin to 2″ gray siltstones
	2′	large silty septaria 2′ to 3′ in diameter
	5′	mostly dark gray shale with a few thin to 3″ gray siltstones; contains a row of large calcareous septaria with cone-in-cone, *Camarotoechia contracta, Strophalosia hystricula,* and fish fragments
	8′	dark gray shale with cone-in-cone which weathers dark red
	2′	large concretions
	5′	dark gray shale with a few thin to 2″ siltstones
	65′	dark gray shale which weathers dark red due to iron oxide with only a very occasional thin to 2″ siltstone; contains two rows of calcareous concretions with cone-in-cone
	3′	dark gray shale with some 1″ to 2″ gray siltstone
	15′	dark gray shale with only a few thin to 2″ gray siltstones
	80′	concealed—believed to be mostly gray shale
	55′	gray shale with only a trace of thin gray siltstone; contains a row of flat calcareous concretions with cone-in-cone

Charlotte Township Section

Section along a small creek a half mile south of northeast corner of Charlotte Township, Cherry Creek quadrangle:

(Ascending order)

Dexterville	6″	gray siltstone bed; nearby exposures contain *Pugnoides duplicatus* in equivalent strata

Dexterville (*Cont.*)

15′ concealed
1′ gray 1″ to 2″ siltstone
10′ concealed
2′ gray thin to 2″ siltstone
5′ concealed
1′ interbedded gray 1″ siltstone and gray shale
5′ concealed
6″ thin to 2″ gray siltstone
2′ concealed
2′ gray 1″ to 5″ siltstone
2′ concealed
1′ gray thin to 3″ gray siltstone
5′ concealed
3′ gray thin to 1″ siltstone containing *Ambocoelia gregaria* and *Camarotoechia contracta*
15′ concealed
10′ gray 1″ to 2″ siltstone
5′ concealed
1′ gray 1″ to 2″ siltstone containing *Ambocoelia gregaria*
8′ gray thin to 1″ siltstone containing small weathered brachiopods
6″ medium gray shale containing *Ambocoelia gregaria* and *Camarotoechia contracta*
3′ gray thin to 1″ siltstone
2′ concealed
3′ gray thin to 1‴ siltstone containing *Pugnoides duplicatus, Ambocoelia gregaria, Strophalosia hystricula,* and weathered *Mytilarca* (?) sp.
3′ concealed
3′ gray thin to 1″ siltstone
8′ concealed
15′ gray thin to 3″ siltstone containing *Pugnoides duplicatus, Ambocoelia gregaria, Athyris* cf. *angelica, Camarotoechia contracta, Cyrtospirifer* sp., *Productella* sp., and *Thiemella tenuilineata*

Ellicott

10′ mostly concealed; a little thin gray siltstone
10′ gray thin to 2″ siltstone containing coquinites of *Ambocoelia gregaria* and *Cyrtospirifer* sp.
1′ concealed
8′ gray thin to 3″ siltstone containing *Ambocoelia gregaria, Camarotoechia contracta,* and *Productella* sp.
8′ concealed
1′ gray thin to 2″ siltstone containing *Productella* sp.
15′ concealed
2′ interbedded gray shale and gray thin to 2″ siltstone
45′ mostly concealed; some gray thin to 3″ siltstone containing *Ambocoelia gregaria* and *Camarotoechia contracta*
11′ intermittent exposures of gray thin to 2″ siltstone with a few gray shales containing *Cyrtospirifer* sp.
2′ medium gray shale

Ellicott (***Cont.***)	11′	mostly concealed; a little gray siltstone
	2′	gray 1″ to 3″ siltstone beds
	8′	concealed
	3′	gray thin to 1″ siltstone with a little interbedded gray shale
	9′	concealed
	1′	gray silty shale
	4′	concealed
	4′	interbedded gray shale and gray thin to 3″ siltstone containing *Camarotoechia contracta* and *Cyrtospirifer* sp.
	11′	concealed
	2′	gray thin to 1″ siltstone containing *Camarotoechia contracta* and *Cyrtospirifer* sp.
	15′	concealed
	2′	interbedded gray shale and gray thin to 2″ siltstone with coquinite of *Cyrtospirifer* sp.
	15′	concealed
	4′	interbedded gray shale and gray thin to 1″ siltstone containing weathered pelecypods

Pope Hollow Section

Along boundary between Carroll and South Valley Townships, Jamestown quadrangle:

(Ascending order)

Cattaraugus	20′	loose conglomerate boulders
	5′	interbedded 1″-3″ light gray siltstone and medium gray shale containing *Cyrtospirifer* sp. and *Productella* sp.
	5′	concealed
	5′	interbedded light gray siltstone and medium gray shale containing *Productella* sp.
	20′	concealed
	1′	light gray siltstone
	25′	concealed
	6′	interbedded light gray siltstone and medium gray shale
	45′	concealed
	1′	interbedded light gray siltstone and medium gray shale
	35′	concealed
	12′	blocks of Panama (?) Conglomerate
	18′	concealed
	5′	red shale
	5′	mostly light gray siltstone with a little gray shale
	15′	concealed
	10′	mostly thin-bedded light gray siltstone
	20′	mostly concealed; conglomerate (?)
	75′	medium gray shale with only a few light gray 1″-2″ siltstone beds
	25′	concealed
	10′	soft gray fissile shale
	15′	Pope Hollow Conglomerate

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y of Chautauqua County
New York

PART II

Pleistocene Geology

BY

ERNEST H. MULLER

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Geology of Chautauqua County New York

PART II

Pleistocene Geology

BY

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1784

> "The earth was made so various, that the mind
> Of desultory man, studious of change
> And pleased with novelty, might be indulged"
>
> *William Cowper*

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Pleistocene Geology of Chautauqua County

BY

Ernest H. Muller

Abstract

Pleistocene glaciation transformed maturely dissected plateau to produce present landscapes of Chautauqua County. Vestiges of preglacial topography persist in the unglaciated southeastern corner of the county, in accordance of summits and in the pattern of major valleys.

Drumlins and rocdrumlins comprise a streamline field that indicates glacier flow from the Erie Basin curving toward the terminal moraine. Decrease in glacier load accounted for progressive southward change in streamline features along flow lines. Preglacial valleys parallel to ice flow were scoured and broadened into a coarse net of "through valleys" that extend across present drainage divides. Valley fill ranges from a few hundred feet in major valleys to a maximum of 1,000 feet in thickness near Markham in Conewango Trough.

A narrow zone of attenuated drift southeast of the Wisconsin terminal moraine corresponds to "outer phase Illinoian" of adjacent Pennsylvania. The Kent Moraine at 2,000 feet above sea level in the southeast corner of the county marks maximum glaciation more than 14,000 years ago. Valley marginal kame delta and terrace deposits northward in the plateau indicate sporadic stagnation of an irregular receding ice margin. Stillstands during general recession are marked by the Clymer and Findley Moraines, which include massive valley-blocking deposits but are thin and discontinuous across intervening uplands.

The Lavery Moraine is the outermost and least conspicuous of several moraines near the northern edge of the plateau. The next younger moraine, like the Hiram clay till of Ohio, has texturally controlled characteristics that may result from assimilation of proglacial lake clay beneath an expanding ice margin. The succeeding Lake Escarpment Moraines, deposited about 12,000 years ago, are at least in part equivalent to the Valley Heads Moraine of the Finger Lakes Region.

Near-shore sediments of proglacial lakes blanket much of the Erie Plain in the northern part of the county. Post-glacial isostatic readjustment tilted strandlines of Lakes Whittlesey and Warren so that they rise about 50 feet in 40 miles from Ripley northeast to Cattaraugus Creek.

Introduction

General Statement

This report (Part II of Geology of Chautauqua County, New York) summarizes information on the physiography and geology of unconsolidated surface materials in Chautauqua County (figure 1). It is based on a program of quadrangle mapping and investigation of glacial deposits in western New York which was begun in 1955. Chautauqua County was the initial target in this program and received primary attention during the field seasons of 1955 and 1956. Principal emphasis in the field was placed on mapping, detailed stratigraphic relationships, and correlation. Supporting laboratory studies have involved analysis of topography and investigation of till constitution, particularly with respect to mechanical and lithologic makeup. Mapping units derived from these initial studies in Chautauqua County have been utilized as investigations were continued eastward during subsequent field seasons to the present (1961).

Part 1—Geology of Chautauqua County, New York, Stratigraphy and Paleontology (Upper Devonian)—is a study of bedrock geology in Chautauqua County. Together, the two reports provide both detailed areal

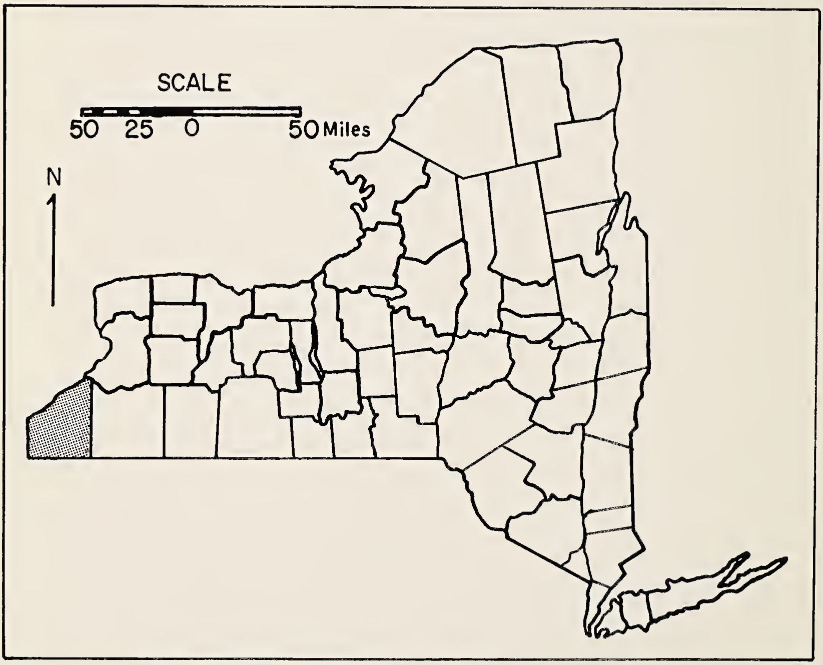

Figure 1. Index map of New York showing location of Chautauqua County.

mapping and a revision of correlations applicable eastward in adjacent counties.

Topographic map coverage of Chautauqua County by quadrangles of the U. S. Geological Survey's 15-minute (1:62,500) and 7½-minute (1:24,000) map series is indicated on figure 2. Particularly current and detailed are the maps of the latter series, which were prepared by photogrammetric methods and released during the course of the present program of glacial mapping. Soils of Chautauqua County are mapped at a scale of 1:62,500 in a bulletin of the N. Y. State College of Agriculture and the U. S. Department of Agriculture (Morrison et al., 1914).

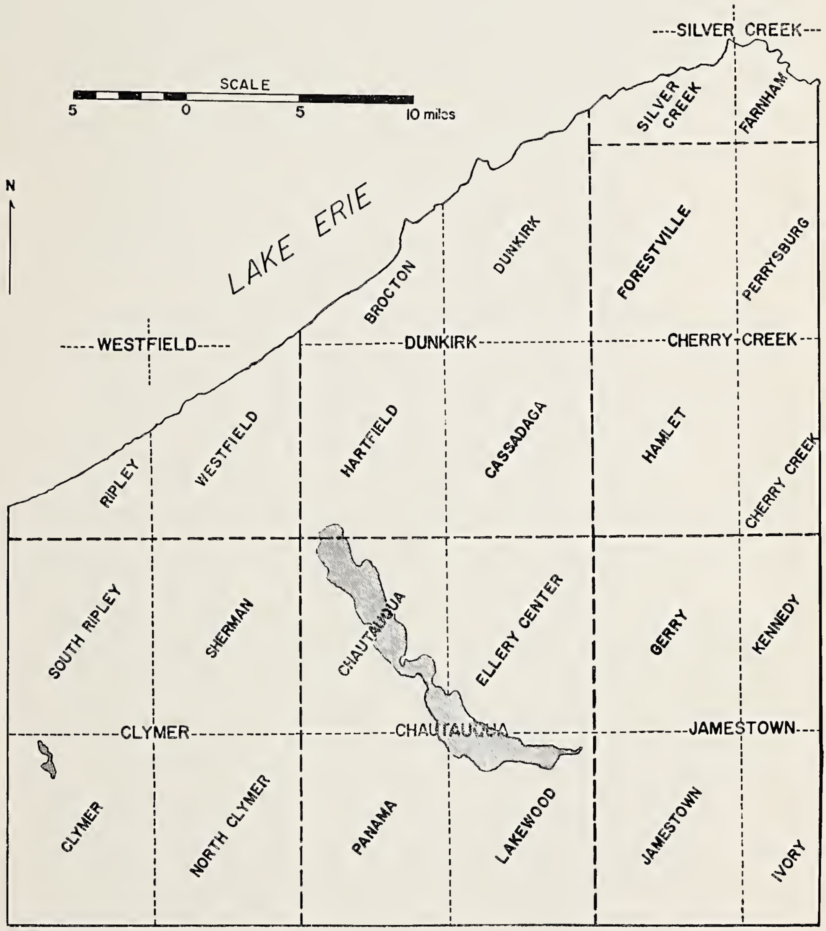

FIGURE 2. Index map of Chautauqua County showing coverage of U.S.G.S. topographic sheets.

Geography

Chautauqua County comprises an area of 1,069 square miles in western New York, bordered on the south and west by the Pennsylvania State line, on the north by Lake Erie, and on the east by Cattaraugus and Erie Counties (figure 3). Except for a triangular area in the northwest beneath Lake Erie, the county is rectangular with breadth east-west of 38 miles

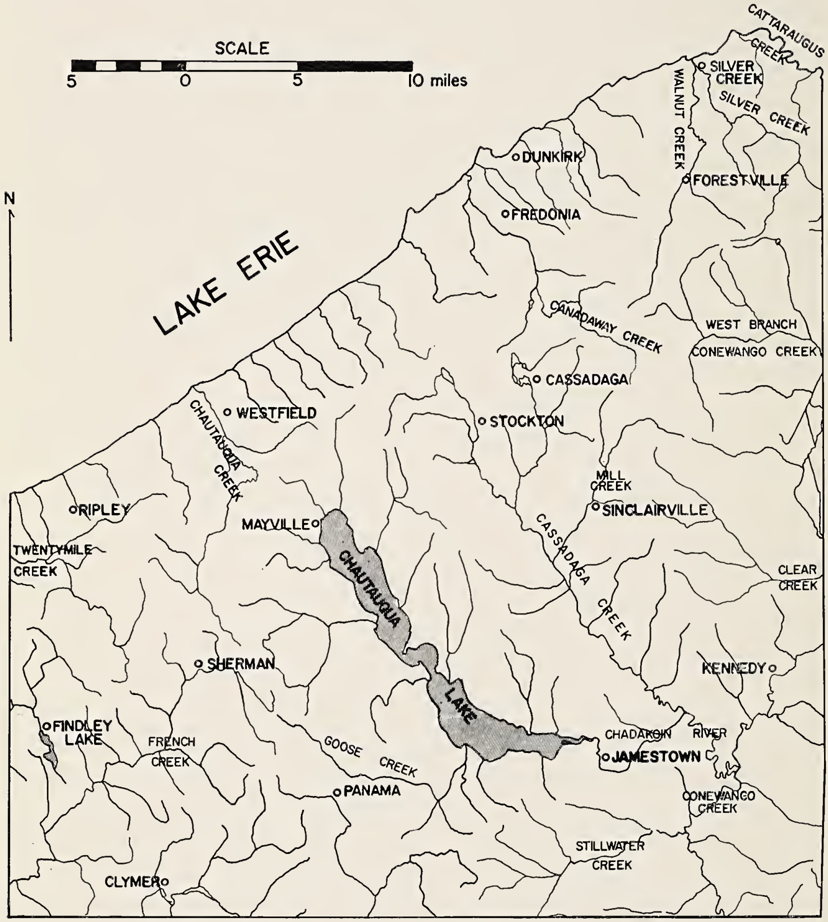

FIGURE 3. Map of Chautauqua County showing place names.

and a maximum dimension north-south of about 40 miles near the eastern border.

Chautauqua County is characterized by moderate relief and rolling landscapes. Maximum range in elevation is 1,575 feet, from the level of Lake Erie, to about 2,150 feet above sea level near the southeastern corner of the county. The maximum continuous slope rises more than 1,300 feet within 8 miles southeast of Dunkirk.

With a population of about 135,000, Chautauqua County includes the well-known resort areas around Chautauqua Lake and on the shore of Lake Erie. Diversified manufacturing is centered around the county's two cities: Jamestown, with 40,000 population at the southeast end of Chautauqua Lake, and Dunkirk, with 18,000 population on Lake Erie. Favorable soil and climate characterize the "Chautauqua grape belt" (Tarr, 1897), a strip several miles wide bordering on Lake Erie. This lowland is a principal east-west corridor followed by two trunk railroad lines and three major highways. South of this zone, in rolling plateau country, hay and dairy farming are dominant in the agriculture of most of the remainder of the county. Second growth timber is increasing in acreage.

Bedrock Geology

As the westernmost county in New York, Chautauqua has much in common geologically with nearby counties in Pennsylvania and northeastern Ohio. The county contains the type section for rocks of the Late Devonian Chautauquan Series. The stratigraphic section (table 1) comprises over 1,800 feet of fine to coarse clastic marine sediments, essentially devoid of limestone. The succession deposited during the Late Devonian represents gradual westward migration of shoreline with resulting coarsening of texture and thickening of bedding as the source of sediment approached.

The lower 1,000 feet of the section are composed largely of shale units which are progressively younger in age southwestward in the lowlands bordering Lake Erie. The Conneaut or Chadakoin Formation, comprising 420 feet of fine sandstone and siltstone, is exposed over most of the Allegheny Plateau in this county. The uppermost 420 feet occur only in the highest parts of the county, northeast of Sinclairville, and near the southeastern corner of the county.

The structure is simple, for the strata are essentially undeformed. They possess very gentle south-southeastward regional dip which results from the position of the county north of the axis of the Allegheny Geosyncline. For further details, the interested reader is referred to the bulletin on the bedrock geology of Chautauqua County (Part I).

TABLE 1. Generalized Geologic Column for Chautauqua County

After New York State Geological Survey	Approximate Thickness (Tesmer, 1954)	After I. H. Tesmer (Part I)
Lower Mississippian		
Pocono Group		
Knapp Formation	20′	Knapp Formation
Upper Devonian		Upper Devonian
Conewango Group		Conewango Group
Oswayo Formation	100′	Cattaraugus Formation
Venango Formation	300′	(includes Panama and Pope Hollow Conglomerate Member)
		Arkwright Group
Conneaut Group		Chadakoin Formation
Ellicott Formation	270′	Ellicott Member
Dexterville Formation	150′	Dexterville Member
Canadaway Group		Canadaway Formation
Northeast Shale	470′	Northeast Shale Member
Shumla Siltstone	30′	Shumla Siltstone Member
Westfield Shale	150′	Westfield Shale Member
Laona Siltstone	30′	Laona Siltstone Member
Gowanda Shale	240′	Gowanda Member
South Wales Shale	70′	South Wales Member
Dunkirk Shale	60′	Dunkirk Shale Member
		Seneca Group
Java Group		Java Formation
Hanover Shale	95′	Hanover Shale
Pipe Creek Shale		Pipe Creek Shale
West Falls Group		West Falls Formation
Angola Shale	235′	Angola Shale

Previous Investigations

LAKE TERRACES

The earliest study of Pleistocene features in Chautauqua County followed recognition of three lake terraces in northern Ohio (Whittlesey, 1838). Winchell (1872) applied the name Belmore Ridge to the middle beach, but Taylor (1897) suggested the name Whittlesey for both the ridge and the lake stage responsible for it. The lowermost of the three beach ridges was assigned to Lake Warren and named the Warren Beach by Spencer (1888). Initially described and studied in Ohio and Michigan, the eastward continuations of these lakeshore features were mapped and described in detail for parts of western New York by Leverett (1895; 1898; 1902) and Fairchild (1907). Although very little subsequent work has been done on the detailed description of these features, their relationships to glacier positions and lake stages in the Great Lakes region as a whole have been clarified in synoptic works of Leverett and Taylor (1915), Leverett (1939), and Hough (1958).

EROSION SURFACES

Investigators of erosion levels in the northern Appalachian Plateaus have reached divergent conclusions. Tarr (1902) briefly ascribed upland remnants in southern New York to a Cretaceous peneplain previously described by Davis (1891). Campbell (1903) recognized the Harrisburg erosion surface as being widespread in northwestern Pennsylvania and Ohio below the peneplain represented by the highest elevations. Campbell inferred from generalized contours on the Harrisburg erosion surface that it had been subjected to doming, but subsequent analysts have disagreed with this conclusion.

Like Campbell, Cole (1935; 1937; 1938; 1941), Fridley (1929), and Ver Steeg (1930) recognized several erosion surfaces in central and western New York and adjacent Pennsylvania. Cole (1938) demonstrated relationships in Chautauqua County by north-south projected profiles of quadrangles from Dunkirk south to Tionesta and east-west from Jamestown to Olean. He recognized the Upland Peneplain (the Schooley Peneplain of Campbell and Ver Steeg; the Kittatinny Peneplain of Fridley) and the Allegheny surface (the Harrisburg of Campbell and Ver Steeg; the Schooley of Fridley).

Countering the tendency to distinguish multiple erosion surfaces, Ashley (1935) suggested that differences in summit elevation in the northern Appalachians represent not different erosion cycles but different amounts of reduction in a single erosion cycle. Denny (1956*a*) examined evidence of structural control during equilibrium reduction of the summit erosion surface in Potter County, Pa.

Carll (1883) and Leverett (1902) discussed evidence of the northward course of the Ancestral Allegheny River, which extended along the east border of Chautauqua County in the valley occupied by the present Conewango Creek.

MORAINES

T. C. Chamberlain (1883) described the principal moraines in Chautauqua County in his report on the "terminal moraine of the Second Glacial Epoch" from North Dakota to Cape Cod. Chamberlain acknowledged his indebtedness to observations by Lewis published the following year. Chamberlain's report involved a notable compilation. and his map of the chief moraines served as the basic source in New York for nearly a half century.

In 1892, Obed Edson wrote a brief and little-known report on glacial features in Chautauqua County. Bonsteel (1896), as part of his undergraduate work at Cornell University, examined evidence of a higher level of Chautauqua Lake.

These reports notwithstanding, knowledge of the glacial geology of Chautauqua County at the outset of the present investigations was based primarily on the work of Leverett (1902). This monograph, summarizing data on unconsolidated sediments in the Erie and Ohio drainage basins, included a map, at the scale of 1:250,000, showing the glacial geology of Dunkirk and Cherry Creek quadrangles, which have been remapped in greater detail for the present report. Although Leverett listed stratigraphic sections and mentioned till characteristics, his emphasis was on topographic tracing of moraines.

Correlation of moraines in Chautauqua County with those of western Pennsylvania and northeastern Ohio was based primarily on lateral continuity (Leverett, 1902) and their relationship to proglacial lake features (Leverett and Taylor, 1915; Fairchild, 1932; Leverett, 1939; Taylor, 1939). Within the present decade, radiocarbon dating of organic material has provided absolute ages which help to pin down the chronology of glacial moraines and proglacial lake stages of the Great Lakes basins (Flint, 1956; 1957; Hough, 1958). Recent investigations suggest the need for revision of certain details of those chronologies (Mason, 1960; MacClintock and Terasmae, 1960; Terasmae, 1959).

GLACIAL GEOLOGY OF ADJACENT AREAS

Studies of glacial geology of adjacent areas gave impetus to the present investigations in Chautauqua County. In Cattaraugus County, Lobeck described the physiography of Allegany State Park (1927*a*) and adjacent parts of the Allegheny Valley (1927*b*); Wilbur (1931) studied the glacial geology of the Randolph quadrangle; MacClintock and Apfel (1944) investigated glacial drift around the margin of the Salamanca re-entrant; and Bryant (1955) refined the Wisconsin drift border. Butts (1910) included discussion of Pleistocene features in his study of the geology of Warren quadrangle, Warren County, Pa.

Recent investigations in northeastern Ohio and northwestern Pennsylvania (Shepps, 1953; White, 1957; White and Shepps, 1952; White et al., 1957) have laid increased stress on stratigraphic and sedimentologic relationships as bases for correlation. Petrographic (Sitler and Chapman, 1955), electron micrographic (Droste et al., 1958), clay mineral (Droste, 1956*a*; 1956*b*), and heavy mineral studies (Dreimanis et al., 1957; Dreimanis, 1960*a*; Lewis, 1960) have been employed in till constitution investigations. Refinements of correlation in Ohio (White, 1960) and of glacial mapping in Pennsylvania counties bordering Chautauqua on the west and south (Shepps, 1955; Shepps et al., 1959; Droste, 1958), as well as the present study in Chautauqua County, have been outgrowths of this concentration of effort on glacial problems in the eastern part of the Ontario Basin.

Physiographic Divisions

Chautauqua County includes three sections distinguishable on the basis of differences in physiographic history and topography (Fenneman et al., 1946). Northernmost is the low-lying belt along the shores of Lake Erie which is part of the Eastern Lake section of the Central Lowlands Province (figure 4), related in history and topography to the basins of the Great Lakes. The remainder of the county is dissected upland belonging to the southern New York and Kanawha sections of the Appalachian Plateaus.

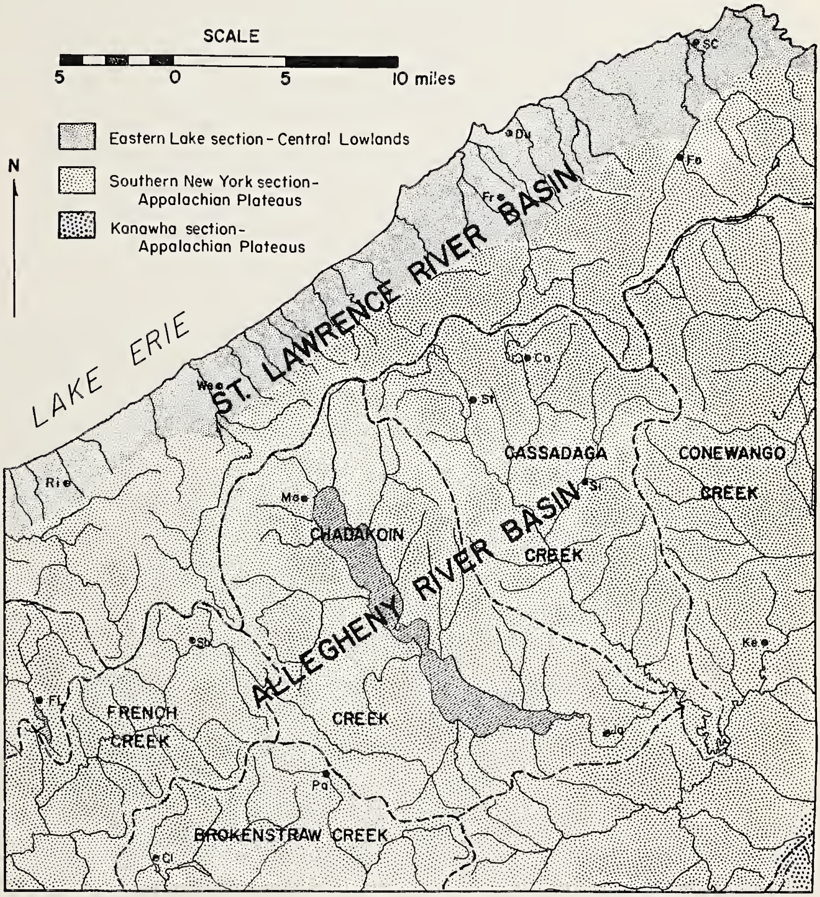

FIGURE 4. Map of Chautauqua County showing streams, drainage basins, and physiographic sections.

The Eastern Lake section of the Central Lowlands Province extends across northern Chautauqua County as a narrow belt (figure 5), less than 2 miles wide in the west, but broadening to about 6 miles in the east where Cattaraugus Creek occupies a southeastward embayment into the uplands. The lowlands comprise a nearly undissected lacustrine plain developed on littoral deposits of proglacial lakes which preceded Lake Erie in the Erie Basin. Strandlines of two such lakes are rather continuously traceable across the county (figure 6). The Erie Plain ranges in elevation from 573 feet at Lake Erie to about 850 feet at the base of the bordering escarpment.

The base of the escarpment constitutes the northern boundary of the Appalachian Plateaus. The southern New York section of the Appalachian Plateaus is a maturely dissected upland developed on essentially flat-lying clastic rocks of Late Devonian age. It differs from other sections of the plateau in that it was glaciated several times during the Pleistocene Epoch, causing scour of the uplands, cutting of troughs, and deposition of deep valley fill. Massive moraines give a northeastward grain to ridge and drainage lines near the north margin of the plateau.

A triangular area of a few square miles in the southeastern part of the county contains some of its highest and most rugged topography. This area comprises the western margin of the unglaciated Salamanca reentrant (MacClintock and Apfel, 1944) and is part of the Kanawha sec-

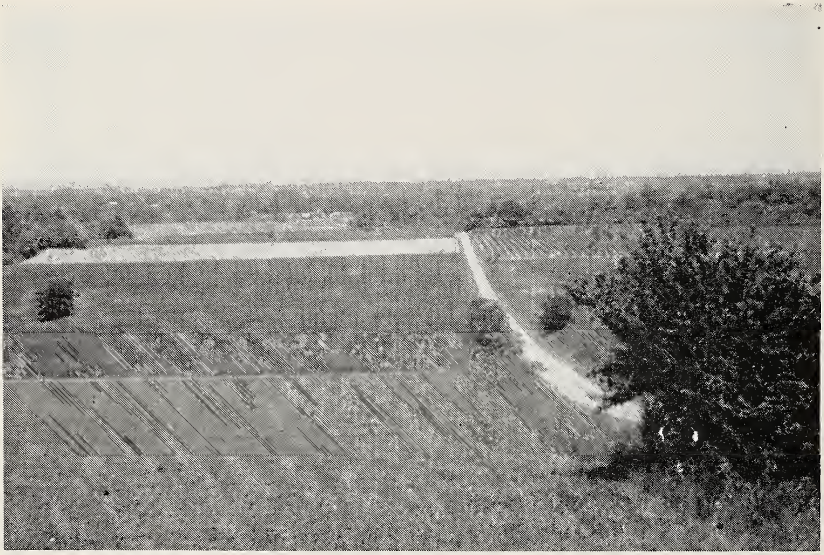

FIGURE 5. View north across the Erie Plain from Route 39 on the bordering escarpment in Sheridan Town. This plain is both a major communications corridor and an important farm belt.

tion of the Appalachian Plateaus. Because it was never glaciated, this area is characterized by less smoothly molded ridges and by more continuous crest lines. Valleys are deeply incised and V-shaped in cross-section, indicating the work of vigorously downcutting streams. Colluvium mantles the lower slopes of hills, but glacial drift is lacking; and, on upper slopes, soils are typically very thin and stony.

Drainage

Chautauqua County includes parts of the Ohio and St. Lawrence drainage basins. The larger part of the county is drained by creeks tributary to the Allegheny River (figure 4) and thence to the Ohio River. The St. Lawrence drainage basin consists of the narrow northeast-trending belt of the Erie Plain and its bordering escarpment. The two drainage basins are separated by several moraine ridges near the top of the escarpment.

Except for Cattaraugus Creek, all streams tributary to the St. Lawrence in Chautauqua County are short. Most rise on the bordering escarpment, descend it with steep gradients and flow north-northwest across the lake plain. A subordinate grain particularly well developed south and west of Westfield consists of west-southwest trending reaches of streams at right angles to the major slope of the Erie Basin. Such streams are controlled by the position of moraine ridges built up during recession of the ice sheet from the plateau margin.

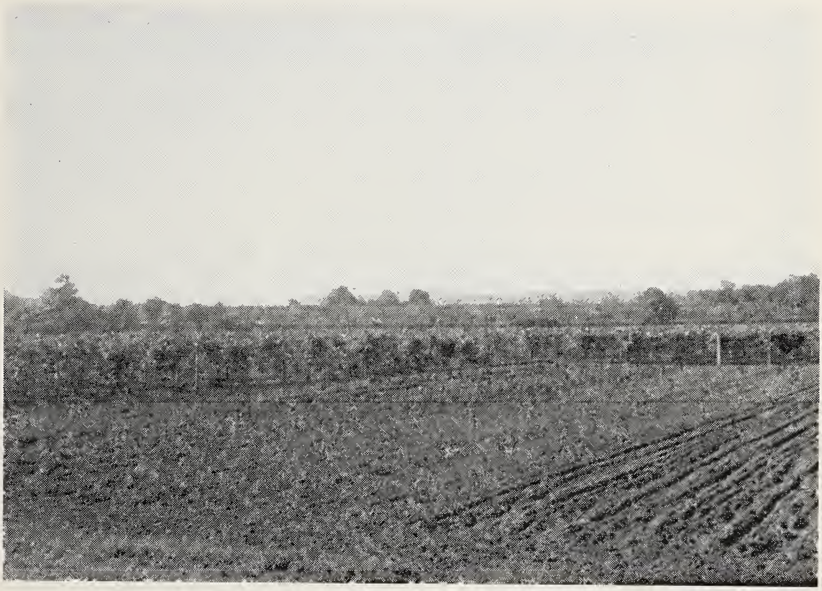

FIGURE 6. View south in the southwest outskirts of Fredonia toward the shore terrace of proglacial Lake Warren in the middle distance.

Most of the north-flowing streams have cut into the escarpment and occupy shallow gullies down its steep slope. Across the lake plain their valleys become incised only within a few hundred yards of the lake shore, leaving the lake plain nearly undissected. Four north-draining creeks rise south of the complex of moraines along the top of the escarpment. Of these, Cattaraugus Creek (figure 3) drains a basin of about 450 square miles in adjacent counties, but lacks any significant tributary in Chautauqua County. The other three—Twentymile, Chautauqua, and Canadaway Creeks (figure 4)—rise on the upland near the scarp and flow northward across the moraine complex, each one breaching the moraines in a steep-walled "gulf" or gorge. Most striking of these, perhaps, is The Gulf of Chautauqua Creek, 3 miles south of Westfield, which is entrenched nearly 500 feet deep.

The portion of the Allegheny drainage basin in the eastern half of Chautauqua County is drained by Conewango Creek. The drainage pattern in this part of the county reflects glacial derangement and is primarily controlled by three major troughs. These troughs, occupied by Conewango and Cassadaga Creeks and by Chautauqua Lake, with Chadakoin Creek its outlet, are broad, open, southeast-trending valleys scoured and enlarged by glacial erosion. Large areas in Conewango Trough are swamp, partly drained by the State drainage ditch. Conewango and Cassadaga Creeks flow southward on gentle gradients developed on extremely thick valley fill. Eighteen-mile-long Chautauqua Lake is nearly split into two basins at the narrows between Bemus Point and Stow. The basin owes its existence to channeled glacial scour which was less effective southward where the trough curves obliquely across the direction of former glacier flow, and the coincidence of subsequent deposition of valley-plugging drift when the margin of the waning ice sheet stood near present Jamestown.

Drainage of the three principal troughs reaches a confluence in Poland Town. The Chadakoin River, which drains Chautauqua Lake, winds indirectly through the kames near Jamestown and across an incompletely reduced part of the upland, to join Cassadaga Creek at Levant. Similarly, Conewango Creek leaves its broad, open valley to curve sharply southwest past Kennedy in a drift-confined channel to the Cassadaga Trough. As Conewango Creek, the combined flow from the three troughs continues southward from Chautauqua County to the Allegheny River at Warren, Pa.

The portion of the Allegheny drainage basin in the western half of Chautauqua County is drained by French and Brokenstraw Creeks. Although the grain of the upland topography parallels the major troughs of the eastern half of the county, the drainage lines lie transversely across the grain toward the west-southwest.

The grain of the upland topography is strongly south-southeastward, controlled by elongate, rounded ridges which are streamline topographic features due to glacial molding. Although headwater reaches of tributary streamlets are controlled by the streamline topographic forms, the principal streams flow generally westward by indirect courses from one open alluvial flat through confined reaches to the next broad-bottomed transverse valley.

The controlling factor in this unconformable pattern is the distribution of recessional moraines. Each major tributary drains an area between moraines. Each is separated from its neighbor by drift deposited across flats and through valleys during stillstands of the waning ice sheet. Thus Goose Creek occupies a drainage basin separated from that of Little Brokenstraw Creek by moraine loops such as the one at Panama. The basin of Brokenstraw Creek is separated from that of French Creek by massive valley-blocking moraines across valleys northeast, north, and west of Clymer. Similarly, the basin of French Creek is bounded on the north by moraine plugs which are particularly well developed across valleys south of Findley Lake, 2 miles north of Sherman and 3 miles west of Sherman, respectively.

Acknowledgments

Initiation of field mapping in Chautauqua County in 1955 was made possible through a Faculty Research Grant of the Cornell University Graduate School. Field expenses were shared that year by the University of Illinois under a grant of the National Science Foundation to G. W. White for till constitution studies in the northwestern Allegheny Plateau. Full sponsorship of the work in Chautauqua County was assumed by the New York State Science Service in June 1956.

The writer acknowledges indebtedness to Professor W. Storrs Cole of Cornell University for encouragement in its inception. Early orientation and advice in the field were provided by Professor George W. White of the University of Illinois, by Dr. John B. Droste of Indiana University, and Dr. Irving H. Tesmer of State University of New York at Buffalo. Professor Paul MacClintock of Princeton University, Dr. Lyman Chapman of the Ontario Research Foundation, Dr. Aleksis Dreimanis of the University of Western Ontario, Dr. Paul Karrow of the Ontario Department of Mines, Dr. John H. Moss of Franklin and Marshall College, and Dr. V. C. Shepps of the Pennsylvania Topographic and Geologic Survey have also contributed valued suggestions in the field or in subsequent correspondence.

Assisting in the field work were Donald C. Noble in 1956 and Charles Ruth in 1957. Douglas T. Lewis and Donald C. Noble helped in phases of the laboratory work.

Radiocarbon analyses for dating of organic material collected in adjacent counties but with direct bearing on correlations in Chautauqua County have been run by the Washington, Yale, Michigan, and Groningen, (Netherlands) Laboratories. The responsible laboratory is, in each case, identified respectively by *W*, *Y*, *M*, or *Gro* preceding the sample number.

Drillers' data were made available by Robert Ehmke of Silver Creek and Howard Cranston of Dansville, by the Hamburg Office of the Iroquois Gas Company, the Water Resources Division of the United States Geological Survey, and the Wellsville Office of the Geological Survey—New York State Museum and Science Service.

Evolution of Upland Topography

Preglacial Reduction

Western New York stood above sea level and was subject to erosion from the end of Paleozoic marine sedimentation to Pleistocene glaciation. No deposits representative of this interval occur in the Appalachian Plateaus. Indirect evidence of this interval can be gained only through detailed physiographic analysis of the erosion surface it produced.

On the premise that modification of the upland surface has been primarily erosional, it is possible to interpret former aspects of the surface from its upland remnants. This may be conveniently and objectively accomplished by superposing a grid over each quadrangle and plotting the highest elevation in each square. Increased generalization may be achieved by use of a coarser grid.

Figure 7 illustrates generalization of erosional topography by use of a grid interval of 6 miles. If no point in the quadrangles was more than 3 miles from a summit remnant representative of the former erosion surface. figure 5 would accurately reflect the gross contour of that former surface. Near the northwestern end of Chautauqua Lake and at the south border where Conewango Creek leaves the county are areas which seem to lack such representative upland remnants. The four western quadrangles are represented by summits generally between 1,800 and 1,900 feet, but they decrease in elevation toward the escarpment on the north. Elevations rise generally eastward, with areas above 2,100 feet in the Cherry Creek and Jamestown quadrangles. The eastward trend of rising elevations continues generally across Cattaraugus County to the Wellsville quadrangle in Allegany County, where Alma Hill—at slightly over

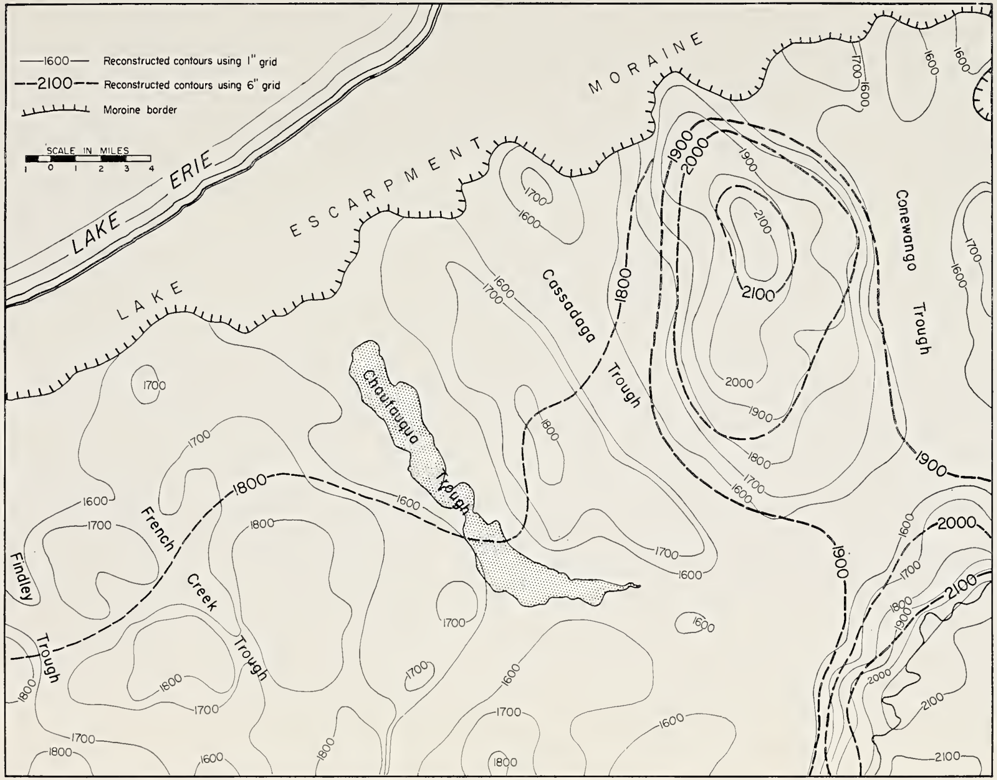

FIGURE 7. Map of Chautauqua County showing hypothetical contours of the reconstructed preglacial erosion surface.

2,400 feet—is the highest elevation in western New York (Cole, 1938, p. 198). Campbell (1903) attributed this eastward rise in summit elevation to slight updoming subsequent to peneplanation, but there is little evidence to support such an hypothesis.

Interpreting projected profiles of the Jamestown-Olean section, Cole (1938) identified two distinct topographic levels. The lower, at about 1,800 feet, comprising the greater part of Chautauqua County, he identified as the Allegheny surface. The higher level, the upland surface, with altitude of 2,300-2,400 feet is well represented in unglaciated parts of the Randolph and Salamanca quadrangles by limited, nearly level areas, suggesting that the regional erosion cycle is in early maturity. Summits at 2,100 feet in the eastern part of Chautauqua County lie between the two identified levels. On the adjacent Warren quadrangle, Cole (1938, p. 193) identified summits at about 2,200 feet as representing "intermediate summit elevations between the typical Allegheny surface and the typical Upland surface."

Both in the southeastern Jamestown and northeastern Warren quadrangles, the highest upland remnants are capped by resistant, thick-bedded conglomerate layers, suggesting that their intermediate elevation may be a function of rock resistance. Rich (1939) cautioned against reliance on elevation alone in relating remnants of a maturely eroded peneplain. No vestiges of flat-topped summits remain in either quadrangle to indicate that the original erosion surface is preserved in Chautauqua County without reduction in elevation. Rather the departure from accordance of summits represents evidence to the contrary. Reduction of this level has been under way long enough for incipient response to rock resistance. The longer reduction continues, the greater the expectable difference between summits developed on strata of contrasting resistance to erosion.

In Potter County, Pa., near the southern limit of glaciation and about 100 miles east of Chautauqua County, Denny (1956*a*) conjectured that preglacial reduction of upland summits was as much as 25 feet to 50 feet, to account for absence of a postulated thick Tertiary residual lateritic soil layer. Similar reasoning, similarly conjectural, applies to probable summit reduction in Chautauqua County prior to glaciation.

Glacial Erosion

Previous studies of erosion levels in New York have either ignored the fact of former glaciation or paid inadequate attention to its role in shaping of the landscape. Little distinction has been drawn between glaciated and unglaciated areas. Tracing of an erosion surface from an unglaciated area into an area of former glaciation may afford evidence that glacial erosion of the uplands was only superficial. Carefully analyzed, in fact, such analysis may give a measure of the reduction of the uplands by glacial scour. On the other hand, careless tracing of erosion surfaces into areas of intensive glacial scour must be accepted only with reservation.

On the 2,100-foot summits in southeastern Chautauqua County, extensive search for bona fide erratic material and other evidence of former glaciation has proven unproductive. Upham (1895) considering the limits of former glaciation marked by attenuated drift, hypothesized the possibility that such drift marks areas of ice accumulation as opposed to ice invasion. Although this hypothesis is not favored for the southeastern corner of Chautauqua County, it may safely be assumed that glacial scour by whatever thin ice margin may have been thrust against this upland was ineffective in reducing its elevation. Apparently, the massive, resistant conglomerate which caps these summits provided the ultimate obstacle which terminated southward invasion by the continental ice sheet at this point.

Within a distance of several miles north of the limit of former glaciation, no elevations approach the level of the unglaciated upland surface. In Charlotte Town, in the southwestern part of the Cherry Creek quadrangle, however, a fairly extensive summit area is above 2,000 feet and in a few places reaches 2,100 feet above sea level. This near accordance with the level of unglaciated remnants in southeastern Jamestown quadrangle strongly suggests that here, also, glaciation was relatively ineffective in summit reduction. All summits are rounded and molded. Glacial drift is thin and dominantly composed of fragments of the underlying bedrock. Erosion, rather than deposition, must have been in effect throughout most of the interval these summits were glaciated.

Assuming a reasonable gradient controlling flow toward the margin of the ice sheet from this area 15 miles north of the terminal moraine, it may be supposed that the ice sheet during maximum glaciation attained a thickness in Charlotte Town of perhaps 1,000 feet. Yet on the basis of the near accordance with summit level in the unglaciated part of Chautauqua County, reduction of summits by glacial scour would appear to be on the order of only 50 to 100 feet. Certainly, lithology of the underlying rock surface may have been a factor in slowing summit reduction, for relatively resistant conglomerate layers are involved. However, in Ellery Town, summits capped by the same strata are more than 200 feet lower. One can only conjecture what factors account for this difference in summit reduction in Ellery and Charlotte Towns.

Streamline Glacial Features

DEFINITIONS

From the moraine complex at the northern margin of the plateau, south to Conewango Creek and the State line, the uplands of Chautauqua County possess a marked north-northwest to south-southeast topographic grain. This grain consists of parallel topographic features produced by the continental ice sheet through a combination of erosion and deposition. The features are drumlins, rock-cored drumlins, rocdrumlins, and other drumlinoid hills. They comprise the Chautauqua streamline field, briefly mentioned but not specifically discussed, in Fairchild's (1907) study of the New York drumlin belt.

Drums or drumlins are smooth-surfaced till ridges, shaped by streamline ice flow. They are composed of till in elliptical hills aligned parallel to the direction of ice flow (Davis, 1896). Composition, form, and origin are all implicit in the definition of a drumlin. A hill which is drumlin-like in form, but does not fully correspond to the definition in all three respects, may be characterized as drumloid or drumlinoid.

Brigham (1901) sought to restrict the term *drumlinoid* by applying it to drumlin-like features composed of glacially abraded bedrock. Fairchild (1907) introduced the term *rocdrumlin* in this sense to indicate specifically the manner in which a drumlin-shaped bedrock hill differs from a drumlin. In present usage, Fairchild's etymologically consistent Celtic compound and the anglicized equivalent, *rock drumlin*, are used interchangeably. Strictly speaking, a rocdrumlin is an erosional feature and therefore closely akin to a *roches moutonné.* By association, rocdrumlin has been used for drumlins consisting of a bedrock core veneered with lodgement till. This usage is to be avoided, and the more specific term *rock-cored drumlin* is preferable for the topographic feature produced by localized plastering of till from the base of the ice as it moved over subglacial bedrock protrusions.

Variation in drumlin form is commonly described qualitatively by such terms as spoon-shaped, cigar-shaped, torpedo-shaped, etc. Such qualitative characterizations are unsatisfactory for classification because drumlins are members of a continuous series which range in breadth, length, and height with no discontinuity. Simple qualitative parameters descriptive of the continuity of variation are needed. Such characterization was suggested by Alden (1905), who likened drumlins to ovoids of various degrees of elongation. More recently, Chorley (1959) has pointed out that the lemniscate loop affords a genetically defensible standard for comparison of streamline forms.

For convenience and ease of comparison, simple length-breadth ratios are employed as a basis for drumlin classification in the present study.

These parameters have been measured for the lowest closed contour of each drumlin. Ratios derived in this manner can be no more accurate than permitted by the contour interval and precision of available topographic mapping. Only where the drumlin base is horizontal and at the level of the lowest closed contour do the length-breadth measurements precisely reflect the dimensions of the drumlin. All ratios are based on measurements on 1:24,000-scale topographic maps drawn with 10-foot contour interval, and are believed adequately to demonstrate the significant differences in drumlin form.

Table 2 proposes a form classification of streamline features which is employed in the discussion that follows. Limiting length-breadth ratios give definition to descriptive terms which can be applied equally to drumlin and rocdrumlin, to depositional and erosional features.

TABLE 2. Form Classification of Glacial Streamline Features

Class	Limiting L/B ratios	Description
1	Less than 2.5	Broad ovoid
2	2.5 to 3.5	Ovoid
3	3.5 to 5.0	Long ovoid
4	5.0 to 8.0	Ridge
5	More than 8.0	Fluting

CHAUTAUQUA STREAMLINE FIELD

Drumlins and rocdrumlins of Chautauqua County represent a single field in that they comprise one consistent pattern of streamline glacier flow (figure 8). Flow lines indicated by the parallel streamline forms are continuous. They show no abrupt change in trend to indicate episodes of glaciation with different directions of ice flow. Only in the area of high relief and high elevation in Carroll Town near the southeastern corner of the county are the streamline forms poorly developed or missing. Even within 2 to 5 miles of the terminal moraine, the elongation of summit ridges and parallelism of present valleys is too nearly aligned with the extension of streamlines from the northwest to be entirely coincidental. Rather they appear to lie directly in line of flow, curving smoothly toward normal to the terminal moraine. It is reasonably to be inferred, therefore, that the entire Chautauqua field of streamline glacial features relates to a single interval of glaciation, during which the centers of glacial outflow and lines of glacier flow were more or less constant.

The long axes of the topographic features of the Chautauqua streamline field lie generally north-northwest to south-southeast. Toward the northern margin of the plateau, they lie nearly north-south, whereas in the southern part of the county they are northwest-southeast. Convergence of flow lines entering Findley and Chautauqua troughs helps to account for preferred drumlin orientation between N15W and N20W north of Findley Lake and northeast of Hartfield. Curvature of flow lines is so gradual that most of the streamline features are oriented between N30W and N40W. South of the southeast end of Chautauqua Lake, the orientation is between N40W and N50W.

Topographic features of the Chautauqua streamline field are diverse, so no single description applies to all alike. Within each drumlin cluster and broadly within parallel belts that trend normal to the lines of glacier flow, the marked similarity of drumlin form and dimension can be readily recognized. Clearly, the factors which controlled drumlin shaping were broadly uniform and changed only gradually during flow toward the margin of the ice sheet. Analyses of factors responsible for drumlin development have long intrigued glacial geologists (Fairchild, 1907; Alden, 1905; Chamberlain, 1894; and many others) because the controlling factors are closely tied to the crucial problem of the nature of glacier flow (Charlesworth, 1957, p. 399).

Progressive change in the character of streamline glacial features is well illustrated along flow lines between Cassadaga and Chautauqua Troughs in Chautauqua, Stockton, Ellery, and Ellicott Towns. Within 20 miles, the ice-molded forms pass in succession from broad ovoid rock-cored drumlins to ovoid drumlins, ridge drumlins, then rocdrumlins, and finally drumlinoid hills.

A belt of large, rock-cored drumlins is developed in the area of considerable relief near the north margin of the plateau. Although only one tier of drumlins in width, the belt extends westward through Mayville and across the Sherman and North Clymer quadrangles with considerable continuity. The prominence of these ridges depends in part on their proximity to the scarp, to glacially scoured through-troughs and to the relief on the subglacial rock surface. Although the ridge at Mayville is 240 feet above the adjacent Chautauqua Trough, most of the rock-cored drumlins of this group are less than 100 feet high. Spacing is uneven with the lateral interval between ridges commonly being more than a mile. Although variable in form, the hills are parallel in elongation and are characterized by smoothly molded slopes and regular contours. Most numerous are broad ovoids, typically abrupt at the north end, tapering and lowering southward. On the lateral slopes of some of the more prominent ridges, bedrock occurs at shallow depth below the surface. The combination of gross features, irregular form, and scattered lateral bedrock exposures suggests that this group of drumlinoid hills owes its characteristics to plastering of lodgement till on protrusions of bedrock into the floor of the glacier. Scouring of grooves may have proceeded simultaneously with lodging of till on the bedrock cores. Boldness of the subglacial relief was such that molding was incomplete and streamlining was only partly achieved.

Southward, the transition from rock-cored drumlins to ovoid drumlins is rapid. The ridges lengthen out. Regularity of drumlin form increases, and slopes are so smoothly molded that minor irregularities attract attention. Spacing is close, the lateral interval between adjacent drumlins ranging typically from 1,000 to 2,500 feet. Many, but not all, of the drumlins, have their greatest height and breadth at distance from the upstream or stoss end equal to 25 to 45 per cent of their total length. Opposite slopes are symmetrically developed, except that drumlins which have the base lower on one side than the other are typically steeper on the flank which has the longer slope. Drumlins of this belt give a roller-coaster effect to east-west roads in Stockton, Chautauqua, Westfield, Ripley, Sherman, and Mina Towns. This is an area of few rock exposures, underlain by the relatively soft shales of the Ellicott Formation.

The parallel grooves and long, narrow depressions between adjacent drumlins control the pattern of minor headwater streamlets. Many saddles between drumlins are broad, rounded drainage divides between oppositely directed gullies parallel to the streamlining. The negative topographic forms possess greater continuity and regularity than their accompanying drumlins. Few have been significantly incised in postglacial time. The paucity of bedrock exposures even within the grooves suggests that they are molded depositional, rather than erosional, features.

In Stockton Town, where the upland at 1,600 to 1,700 feet above sea level is not significantly stream-dissected, the length-breadth ratio is about 3.3 on the average, with one out of four drumlins being long ovoids. Individual drumlins at the margin of the group tend to possess markedly lower length-breadth ratios than do those toward the center. Comparison of the Stockton drumlin group with a group between the headwaters of Twentymile and French Creeks in Mina and Ripley Towns illustrates this relationship further. In this latter cluster, ovoids predominate, and drumlin height averages a third more than in Stockton Town. The few elongate ovoids are in the center of the group. The suggestion that elongation bears an inverse relationship to relative flow resistance (Chorley, 1959) would seem to be borne out by these observations.

Average elongation of drumlins increases southward from Stockton into Ellery Town at elevations above 1,700 feet along the undissected axis of the upland between Cassadaga and Chautauqua Troughs. Average length-breadth ratio a short distance north of Ellery Center is 5, though long ovoids are dominant toward the edge of the group. Few of the ridge drumlins are as much as 50 feet high. The tendency for the highest and broadest part of the drumlin to be upstream from the middle of the drumlin is less marked than farther north. Aligned drumlins and multiple aligned summits on a single ridge are noted. Spacing is less than 1,000 feet laterally in many cases (figure 9). As far south as Ellery Center, the streamline forms are primarily depositional with an apparently progressive decrease in drift thickness southward. Bedrock is exposed in gullies between drumlins, but otherwise does not generally crop out in either ridge or groove. Observations do not presently permit conclusions as to whether the underlying bedrock surface is grooved and streamlined. If such is the case it confirms the probability that erosional dominance during maximum glaciation was followed by depositional dominance during thinning and waning of the ice sheet.

South of Ellery Center, the transition from drumlin to rocdrumlin takes place in an area where drift mantle is decreasingly extensive. Bedrock is exposed not only in gullies and on the flanks of steep-sided drumlins, but also across drumlin crests. Roadcuts a couple of miles due east of Ellery Center reveal shale and thin-bedded siltstone of the Amity Formation, essentially without drift cover at the stoss or impact end of a rocdrumlin. The initially horizontal stratification is crumpled and broken as though about to be drawn up into the load of the overriding ice sheet. The thinness and discontinuity of the veneer of lodgement till

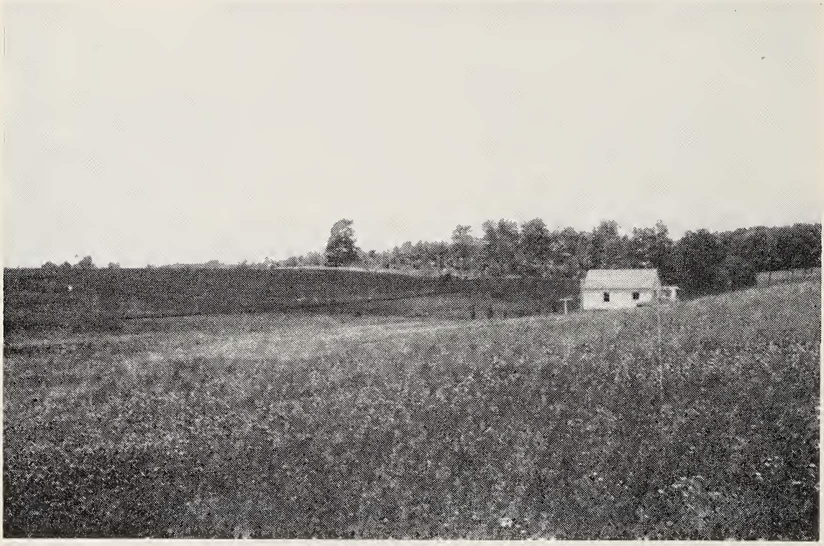

FIGURE 9. View northwest obliquely across trend of streamline glacial features from one ridge in foreground to a second in midground at left. Note particularly the smoothness and regularity of slopes. Ellery-Centralia Road, 1 mile north of Ellery Center.

suggest that the sole of the ice sheet carried little debris to become lodged or dumped as the glacier thinned during the waning hemicycle of glaciation. The crests of streamline forms south of Ellery Center are typically in the downstream half of the ridge, signaling the fact that the majority of the features are rocdrumlins rather than drumlins. The transition is gradual, however; and, even as far south as Oak Hill Road, just west of Jamestown Airport (figure 10), a few ridge drumlins occur directly down-flow by 3.5 miles from the previously mentioned rocdrumlins east of Ellery Center. In this transition zone from Ellery Center to the Chadakoin River, lateral spacing of streamline forms becomes more open. The forms become less regular and more diverse.

The continuation of flow lines of the Cassadaga-Chautauqua Upland across the valley of Chadakoin River brings them into Ellicott Town, southeast of Jamestown. Here, the streamline forms are broad ovoid drumlinoid hills more than 2 miles long, composed of bedrock with thin and discontinuous veneer of lodgement till. Shallow gullies and low road cuts expose shale and siltstone of the Ellicott and Dexterville Formations. Lateral spacing between ridges is .5 to 1 mile. The uplands stand 200 to 300 feet above the bottoms of adjacent through valleys, but individual ridges are generally less than 125 feet high. Grooves are open and regular. Several, like the one followed by Route 62 for 2 miles south from Jamestown to Stillwater, extend completely across the upland from the Chadakoin to the Stillwater Valley. Except for the 1,620-foot

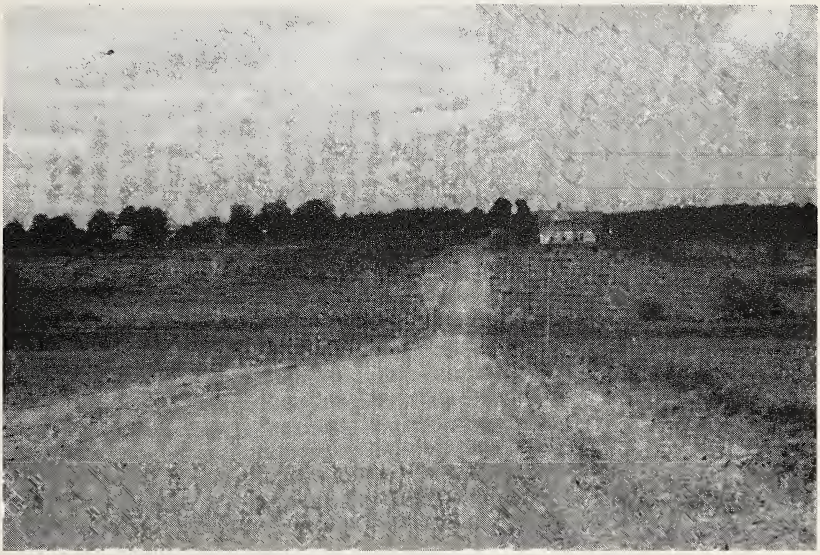

FIGURE 10. View west across glacial groove between streamline ridges near Oak Hill Road, northwest of Jamestown Airport.

summit in the southeast corner of Willard Park in Jamestown, the highest point on each ridge is well south of center. Closed contours on the summits are lemniscate curves with apex toward the stoss end, indicating the bedrock character of the hills. The principal features of these hills result from glacial erosion due to intensive scour of an exposed upland remnant of moderate relief.

Discussion

Terminology and Classification

As suggested by Fairchild (1907, p. 394) and plainly stated by Flint (1957, p. 68), streamline molded features comprise a continuous series "with complete gradation, independent of outward form and within a single field, from rock to drift." Kupsch (1955), proposing a theory of drumlin origin, states that "roches moutonnés, crag and tail, rock drumlins, drumlins with stratified drift cores and drumlins with till cores would form one series, all composed of modified nuclei with no, a little, or much glacial material lodged on their lee" sides.

In view of the gradational relationships among streamline glacial features, it is not surprising that lack of clarity exists in usage relating to form, structure, and genesis of these features. Table 2 (page 19) is a classification of streamline ridges by form, applicable without regard to structure or genesis. Table 3, below, suggests the nature of the continuous series between streamline molded features of erosion (on the left) and of deposition (on the right).

Table 3. Genetic Classification of Streamline Glacial Features

Erosion dominant	Erosion and deposition	Deposition after erosion	Deposition dominant
Crags and tails		Cored drumlins	Drumlins
Crags with bedrock tails	Crags with drift tails	Rock-cored drumlins	
Roches moutonnés		Drift-cored drumlins	
Rocdrumlins			

As defined by Fairchild (1907), rocdrumlins are abraded bedrock hills. They are erosional rather than depositional features and therefore are classed with crags and tails and roches moutonnés. All three are products of scour and quarrying. Scour is particularly effective on the stoss or impact end of a bedrock hill. Quarrying is particularly effective in the "dead space" in the lee of a bedrock hill which projects into the base of a glacier. The three erosional streamline forms differ in the relative importance of these two processes of glacial erosion.

Crags and tails are produced where bosses of particularly resistant rock protruding into the base of the glacier protect less resistant material in the lee. The tails in such cases may consist either of bedrock or of drift deposited in the zone of reduced ice pressure downstream from the resistant rock boss. Roches moutonnés are produced where scour at the impact end of the rock hill is matched by quarrying of large joint-defined blocks of massive bedrock in the lee. Where a bedrock hill is composed of finely jointed, thin-bedded, readily erodable material, scour is favored and quarrying is minimized in effectiveness. The result of glacial erosion in such a case is an elongate, streamline hill which lacks the abrupt lee end characteristic of a roches moutonné. In some cases, as on weakly indurated shale, such a hill may even be steeper at the stoss end. Such a bedrock hill is a rocdrumlin and may commonly be nearly indistinguishable in form from a drumlin.

Whereas the existence of crags and tails in a landscape is evidence of isolated bedrock knobs of superior erosional resistance, none of the other streamline features carries such implication of differential erosional resistance. Roches moutonnés suggest the existence of massive, typically igneous or metamorphic bedrock. In Chautauqua County, the most massive strata are lensing beds of quartz conglomerate in the Cattaraugus Formation. The remainder of the section is typically thin bedded to medium bedded and well jointed. Accordingly, neither crags and tails nor roches moutonnés are to be sought in the area of this study.

Where localized accumulation of lodgement till on a subglacial protrusion can be demonstrated or is reasonably hypothesized, the feature may be referred to as a cored drumlin. The protrusion into the base of the former glacier may be either composed of bedrock or of drift. In the former case, the rock core is typically scoured and abraded, giving evidence that erosion preceded deposition of lodgement till. The distinction between rocdrumlin and rock-cored drumlin is not sharp, and the two terms have unfortunately been used interchangeably. The latter term should be used where bedrock is not naturally exposed in the surface of the elongate hill. In such case, thickening of lodgement till may account for part of the topographic high. Drift-cored drumlins, typically with a veneer of lodgement till, include Upham's "Madison type" (1894) and related features described among others by Millis (1911), Slater (1929), and Kupsch (1955). The apparent significance of erosion in the origin of cored drumlins has kept alive the long discussed opposition of views as to the destructional and constructional origin of drumlins.

DRUMLIN ORIGINS

Gravenor (1953) has recently reviewed the extensive literature on conditions responsible for drumlins. Although it is generally agreed that drumlins and related streamline features are produced beneath actively flowing ice and that they possess forms which offer minimum resistance to ice movement, agreement appears to cease at this point. Broadly speaking, Gravenor grouped early theories of drumlin origin as either erosional or depositional.

Early variants of the erosional theory by Upham (1894) and Millis (1911) are considered improbable, and Tarr's (1894) association of drumlins with subsequently over-ridden moraine belts cannot be generally applicable. Gravenor proposed a modified erosional theory involving deposition of moraines of ice advance during the waxing hemicycle of glaciation and subsequent molding and shaping during maximum extent of the ice. Kupsch (1955) hypothesized a similar origin involving advance over stagnant ice deposits for the gravel-cored drumlins near Dollard, Saskatchewan. Extensive exposures in one of these drumlins show it to be composed of a nucleus of sand and gravel with a tail of till and a veneer of lodgement till. Origin by deposition of stratified drift, subsequent erosion, and ultimate plastering of a veneer of lodgement till seems indicated and probably occurred during a single glaciation. The role of erosion in shaping of drift-cored drumlins is convincingly demonstrated. Such drumlins are not known to occur in Chautauqua County, however.

Fairchild (1907) early hypothesized a depositional origin for drumlins in New York, visualizing their development as taking place by the plastering on of lodgement till due to greater friction between clay and clay than between clay and ice. In point of fact, the till of which drumlins are composed is not either uniformly or notably clay-rich. The accretion hypothesis, nevertheless, has received recent support from till fabric analyses (Hoppe, 1951; Wright, 1957), which show accretion of till by lodgement with strong preferred orientation parallel to drumlin trend. Wright (1957, p. 27) noted the dominance of relatively steep "up-glacier" plunge of elongate pebbles in till of the Wadena drumlin field in Minnesota. Holmes (1941) in central New York observed more nearly horizontal attitude as characteristic in lodgement till. Wright suggested that the pronounced "up-glacier" plunge may be a clue to the mode of lodgement during till accretion under conditions which favor drumlin development.

In the light of studies such as those referred to above, it is clear that drumlins are polygenetic. Nothing observed in the course of the present study gives reason to question Fairchild's conclusion that New York drumlins are primarily depositional. One exposure near the extreme southwestern corner of the county revealed a streamline hill consisting of a drift tail on a rock-cored nucleus.

In an attempt to identify critical factors responsible for drumlin formation. Aronow (1959) compared drumlinized and drumlin-free portions of the Warwick-Tokio map area in North Dakota. He assumed that the responsible factor must be sought in the nature of the basal load, the initial terrain and rock structure of the subglacial surface, or the nature of the former ice sheet itself. Failing to distinguish fundamental differences in the stoniness and plasticity of the till, or in the nature of the subglacial surface between the drumlinized and drumlin free areas, he concluded that "something" in the physical or dynamic character of the now vanished ice accounts for the presence of drumlins in one area and their absence in another.

The present study affords no support to Fairchild's stress on clay content as a significant factor in till accretion. Chautauqua County drumlins are composed of till which is not notably clay-rich. Typical mechanical analyses show the till to be composed of subequal proportions of sand and silt, with the clay fraction ranging from 5 per cent to 15 per cent. By coincidence, mapped areas of clay till are notably not drumlinized, being found primarily in patches of end moraine in certain through troughs near the north edge of the plateau.

Although the area of drumlins in Chautauqua County is largely within the mapped area of Ellicott shale and siltstone (Tesmer, 1954; Part I), areas in the southeastern part of the county underlain by similar rocks are characterized by drumlinoids and rocdrumlins. In much of the drumlin belt, bedrock exposures are so sparse and widely scattered that it is difficult to conceive of bedrock composition through its downstream influence on till quality exerting a significant control on drumlin development. On the basis of these considerations, it is concluded that till constitution is not a fundamental factor in drumlin development.

On the other hand, quantity of drift may be a determining factor controlling the form and type of streamline feature produced by glaciation. The progressive and continuous southward change in character of the Chautauqua streamline field as represented, for instance, between the Cassadaga and Chautauqua Troughs is suggestive evidence of such a relationship. The drumlin belt commences directly south of the moraine complex along the plateau border in the north. Average thickness of upland drift cover appears to decrease southward. This is consistent with the previously discussed evidence (page 17) of the relative ineffectiveness of glacial scour in reduction of upland summits in the southern half of Chautauqua County. Inasmuch as a supply of drift is a prerequisite for drumlin development, it may be assumed that drumlins are favored downstream from a readily eroded terrane, or in a position where the transition from erosion to deposition by actively moving ice takes place. The tendency of glacial modification to produce streamline features would, however, seem to be independent of this control, as suggested by the southward transition from drumlins to rocdrumlins.

Russell (1895) suggested that the concentration of debris within a part of a glacier should reduce its plasticity, decreasing the rate of flow. Drumlins were conceived by Fairchild (1907) as "the short lines of temporarily diminished pressure and lagging flow" which resulted therefrom. More recently, Chorley (1959) has related elongation of drumlins to flow resistance. The more elongate ridges afford less resistance to flow. By the same token, they may be expected to form where decreasing concentration of basal load produces decreased resistance within the sole of the glacier. The apparent southward decrease in average thickness of upland drift and progressive elongation of drumlins from Stockton Town toward Ellery are consistent with this relationship.

It must be inferred on the basis of the present study that subglacial topography may play a significant role in determining the form and type of streamline feature produced by glaciation. Drumlinoid hills near the scarp in the north and rocdrumlins in the area of considerable relief in the southern half of the county demonstrate this relationship. The intervening drumlin belt, however, shows no such conclusive control by underlying topography, and it may be inferred that, with increasing thickness of drift cover, the influence of subjacent bedrock topography decreases. On the basis of the drumlin pattern on the Ontario lake plain, Fairchild (1907) hypothesized that drumlins result from shifting lines of temporarily diminished pressure, not controlled by external factors such as subglacial protrusions.

Although concentration of basal load and irregularities in the subglacial surface are inferred above to affect the form of glacial streamline features, it is apparent that ultimate understanding of the manner in which such features are formed will depend on knowledge of the dynamics of the glacier. Something inherent in the flow of a glacier is involved. The similarity of form of erosional and depositional streamline features gives emphasis to the suggestion of Fluckinger "that ice moves in a wave form because of the friction of the moving ice with the underlying bedrock" (von Engeln, 1938). Although Demorest (1939) convincingly denied validity of Fluckinger's postulated wave motion in ice, other aspects of basal flow of glaciers remain to be examined.

It is here hypothesized that localized resistance to flow at the base of a glacier produces compressive flow with laterally diverging streamlines and rising shear zones over the area of localized resistance. The cause of such resistance to flow may be a protruding part of the subglacial floor, or a concentration of basal debris. Where basal ice is at the pressure melting point with no cold reserve, the build-up of pressure on the upstream side of such a center of local flow resistance causes limited melting of ice. Added to the small factor of basal melting by geothermal heat flux, this melting facilitates flow of the basal ice and transfer of debris from the ice to the subglacial surface by lodgement. If till fabric represents "fossil" orientation of cobbles in the basal ice of the former glacier, rising shear zones due to compressive flow may well be the cause of the dominance of up-ice plunge of elongate pebbles noted by Wright. If the basal ice is relatively debris-free, abrasion rather than lodgement takes place, producing a rocdrumlin or a related erosional streamline feature.

Conclusions as to Origins of Upland Topography

The foregoing analysis of upland topography in Chautauqua County leads to the following conclusions and inferences regarding the physiographic history of the area and the origins of similar topographic features in other areas:

1. Near accordance of summit elevations in adjacent unglaciated parts of the Allegheny Plateau and in the least intensively glaciated portions of Chautauqua County evidences preglacial base leveling, rejuvenation, and mature dissection.
2. Imperfect accordance of summits below the Upland Peneplain has been attributed to successive erosion intervals; but, in the unglaciated areas adjacent to Chautauqua County, it appears to result from lithologic and structural control of rates of summit reduction by normal erosion processes.
3. Projection of the Upland Peneplain from unglaciated areas across the limit of glaciation and northward into Chautauqua County affords a measure of the effectiveness of glaciation in summit reduction. As far as 15 miles north of the glacier limit, summit reduction by glacial scour may have been as little as 50 to 100 feet.
4. Glaciation of the upland surface produced a field of streamline features covering most of Chautauqua County and consisting of drumlins, rock-cored drumlins, rocdrumlins, and other drumlinoid hills.
5. Flow lines suggested by the Chautauqua field of streamline glacial features comprise a single consistent system curving continuously from nearly normal to the plateau border in the north to approximately normal to the terminal moraine in the southeast. Continuity

of this field suggests a considerable persistence of outflow from the area of present Lake Erie at least during late Pleistocene glaciation.

6. Within any given cluster of streamline features, marked similarity of type and form and dimension can be readily recognized. Deviation from typical characteristics in any cluster is apt to be most marked in individuals adjacent to through valleys.
7. Progressive change in the character of streamline glacial features along the lines of flow suggests a gradual change in the sole of the glacier. It is proposed that progressive southward decrease in basal load may account for this change.
8. Boldness of subglacial relief in some areas affects the type and form of streamline glacial feature developed by glaciation, including not only erosional features but rock- and drift-cored drumlins.
9. The ultimate key to the understanding of the origin of streamline glacial features will depend on knowledge of the dynamics of the debris-littered sole of now vanished ice sheets.

Through Valleys

General Statement

Among the striking features of the glaciated southern New York section of the Appalachian Plateaus are the major valleys. The broad flat bottoms of these partly drift-filled valleys contrast with the dissection and streamline glacial features of the upland. Because many of the valleys extend directly across present stream divides at depths of several hundred feet below the upland surface, they have been termed *through valleys* (Tarr, 1905). For reasons stated below, these features might more accurately be termed *through troughs*, but the earlier term as established in the literature (e.g., Holmes, 1952; von Engeln, 1961) has come to connote the combined glacial and fluvial origin to which they owe their character.

In plan, the through valleys possess patterns suggestive of origin by stream erosion, but glacial modification is a dominant control in their form and profile. Some valleys are gently winding, like deeply incised stream valleys, though sharp curves and meanders are notably lacking. Tributary systems are clearly recognizable and in many cases reflect drainage patterns distinctly unlike that of the present. Although dendritic patterns are typical, trellis arrangement is also developed, with recognizable obsequent, resequent, and subsequent elements (Monnett, 1924). The valley walls are notably regular and smoothed. Spurs have been truncated abruptly, producing steep valley walls such as that on the west side of Cassadaga Trough north of Falconer. The profile of the typical through valley in cross section is U-shaped from the upland shoulder to the drift filling in the bottom. In many cases, the bedrock valley beneath the drift forms a continuation of the catenary curve of the valley walls. In long profile, the bedrock valley bottoms may or may not possess consistent regional gradient. In other parts of New York the deepest parts of certain bedrock valleys lie below sea level, indicating the erosional effectiveness of concentrated glacial scour.

For convenience, each of the principal through valleys of Chautauqua County is referred to by the name of the major drainage feature which occupies a part of it. From east to west, the principal through valleys (figure 8) are the Conewango, Cassadaga, Chautauqua, French Creek, and Findley Troughs. The relationship of present drainage to these inherited features has been briefly discussed in a previous section (pages 11-13). It is clear that in all cases the present streams have played very minor roles in modification of the troughs they occupy. All the streams are underfit and prior to development of present drainage systems they readily spread through extensive swamplands during flood seasons. Present data are adequate only to suggest the pattern of preglacial drainage which controlled the development of these through valleys.

Conewango Trough

The largest of the through valleys is occupied by Conewango Creek along the eastern border of the map area. Prior to glaciation, the Ancestral Allegheny River with its headwaters in Pennsylvania flowed past Olean and Salamanca in Cattaraugus County; thence, instead of curving southward as at present, it continued northwest through Randolph Town and within the Chautauqua map area, past Rutledge, Cherry Creek, South Dayton, and Markham (Carll, 1883; Leverett, 1902) (plate 1). Few wells penetrate deeply enough to establish the long profile of the bedrock valley. The limited available data are consistent, however, in suggesting a gradient from nearly 1,000 feet above sea level where the Allegheny presently leaves its ancestral channel in Cattaraugus County, to about 800 feet where the ancestral valley enters the map area and about 400 feet where it leaves the map area south of Markham. At Gowanda, 6 miles northeast of Markham, where the drift-filled valley leaves the plateau, bedrock exposures on opposite sides of the valley are only .7 mile apart, yet a municipal well between them is reported to have penetrated 320 feet of drift. Although these limited data suggest a consistent northward gradient, additional information may define enclosed basins on the bedrock surface produced by differential glacial scour. The thickness of fill in the axis of the valley near Markham is about 1,000

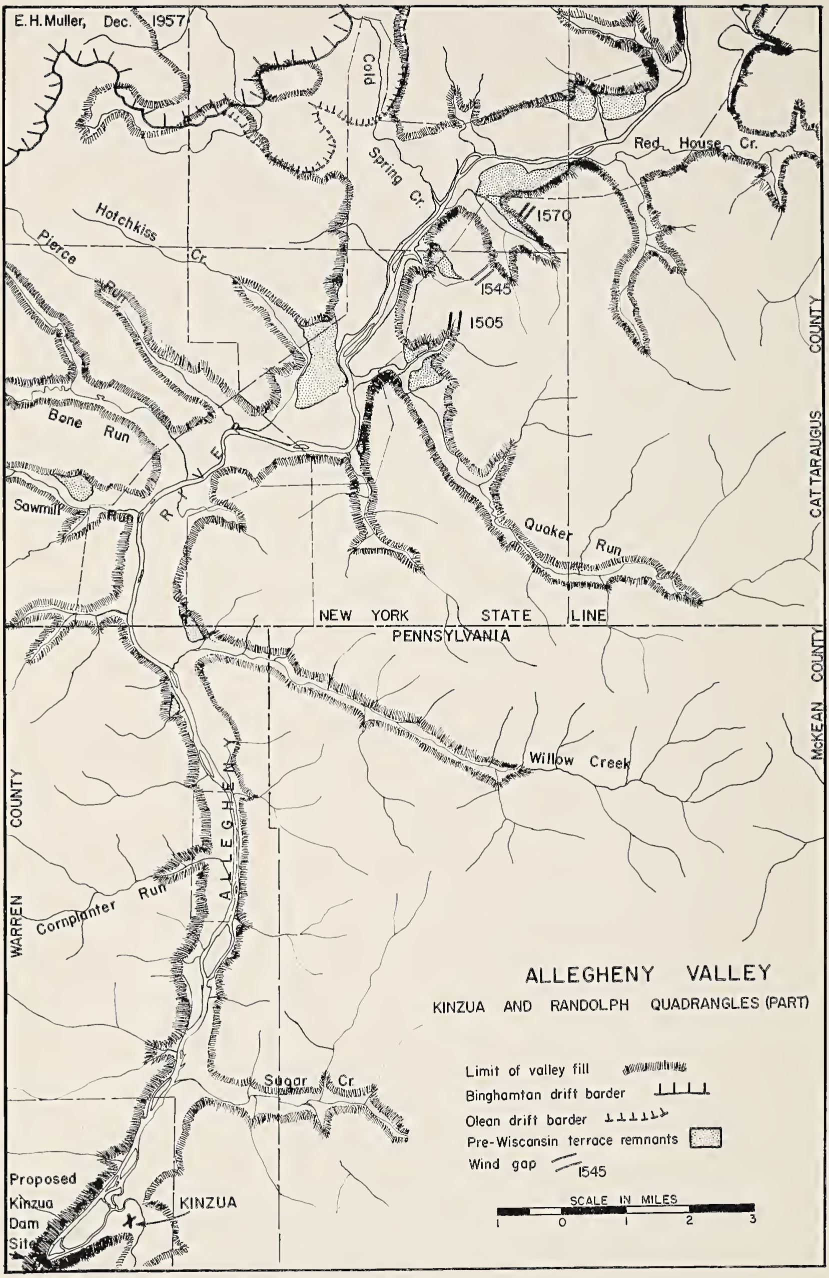

FIGURE 11. Valley of the Allegheny River between Salamanca, N.Y., and Kinzua, Pa., illustrating the valley segment developed by diversion of the Ancestral Allegheny River across the Kinzua Col.

feet, which is believed to be the greatest depth to bedrock in New York west of the Finger Lakes.

Because of its bearing on pre-Wisconsin glacial history of Chautauqua County, additional information on the Allegheny Valley is pertinent. For about 20 miles south from the point where the Allegheny River leaves its ancestral valley (figure 11), it follows a valley which narrows gradually downstream (Muller, 1957). As far as Kinzua, 10 miles south of the State line, tributaries are barbed, and this valley segment gives the appearance of having been cut by a northward-flowing tributary of the Ancestral Allegheny River.

It is inferred that imponding of the Ancestral Allegheny by an early advance of the continental ice sheet from the north created a temporary lake in the reaches of the Ancestral Allegheny River in southern New York. In time, waters of this temporary lake overflowed southward across the lowest available divide, first notching it, then cutting an 800-foot-deep gorge through the col at Kinzua. Structure contours on the oil-bearing Clarendon Sandstone and the Salamanca Conglomerate define a shallow syncline with its axis through the Kinzua Gorge (Butts, 1910). It may be that this structure played a controlling role by favoring reduction of the preglacial divide more rapidly than at the heads of other tributaries of the Ancestral Allegheny. The Kinzua Col had been cut to essentially its present depth before deposition of the earliest glacial materials in Chautauqua County.

Although northward drainage of the Ancestral Allegheny, as postulated by earlier investigators, is supported by presently available data, it is probable that ancestral streams in most other through valleys of Chautauqua County flowed southward. Tributary troughs of Slab Creek and North Branch Conewango Creek form south-pointing acute angles at their junctures with Conewango Trough southwest of Markham and South Dayton, respectively. At the head of Slab City Trough, 2 miles east of Nashville, a gas storage well entered bedrock at 157 feet below the surface. At East Mud Lake, near the head of North Branch Conewango Creek, a water well penetrated 186 feet of drift without encountering bedrock. Although these wells indicate moderately thick drift, they do not compare with the depth to bedrock figures at comparable locations in the Ancestral Allegheny Valley. Assuming that the two tributary troughs originated by scour of preglacial valleys, the initiating streams may be inferred to have had barbed confluences with the Ancestral Allegheny River. Deepening of the canyon of the Ancestral Allegheny as it approached the margin of the plateau may have induced piracy of resequent streams with courses southward from the scarp.

The West Branch of Conewango Creek represents an interesting case of glacial derangement. It rises in a narrow, north-trending valley, but is deflected eastward in a valley which narrows toward Hamlet, and crosses an inferred former divide into the deeply filled tributary system of Conewango Trough. It appears probable that preglacial drainage in the valley of West Branch was northward past Mud Lake and Forestville, approximately following the course of Walnut Creek.

Other Through Valleys

In an unpublished report on a potential water source for the city of Dunkirk, H. L. Fairchild concluded that ancestral drainage in Cassadaga Trough was southward, in the direction suggested by the acute angle of its juncture with Stockton Trough. The depth of drift on the divide at the head of Cassadaga Trough is more than 130 feet, but southward gradient on the bedrock surface is suggested by limited available data. In Stockton Valley, such gradient is suggested by depth to bedrock which increases southward from 140 feet at Stockton Village to more than 180 feet at South Stockton. Sixteen miles south, down-valley, the rock floor is nearly 500 feet lower than at Stockton.

Available data are not adequate to establish details of bedrock topography beneath the present divide at the north end of the Chautauqua Trough. The angle of juncture of Goose Creek with Chautauqua Trough affords ambiguous evidence of the direction of preglacial flow, but the

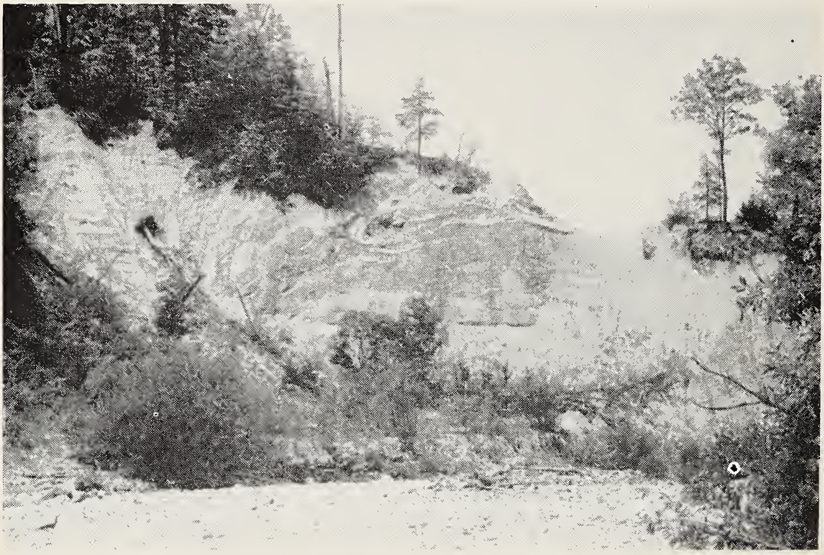

FIGURE 12. Kame gravel deposited in a small proglacial lake and exposed in 80-foot bank of the mile-long, drift-filled interglacial part of The Gulf, Chautauqua Creek, west of Mayville.

eastward narrowing of Chadakoin Valley between Jamestown and Falconer is suggestive of northward ancestral drainage. In The Gulf, Chautauqua Creek flows for nearly a mile through a drift-walled gorge where intensive incision at the plateau margin has partly excavated a short reach of a filled preglacial or interglacial valley (figure 12). Both upstream and downstream, the creek presently occupies a confined bedrock canyon. A more probable course of ancestral northward outflow from Chautauqua Trough is suggested by depth to bedrock in a well 4 miles east-southeast of Westfield near the Westfield-Portland town line. This well, located north of the present divide but up on the scarp, penetrated more than 400 feet of drift. This thickness of drift is comparable with depths to bedrock encountered near Jamestown Junction and Bemus Point in the Chautauqua Basin.

French Creek and Findley Troughs do not extend to the plateau margin, and apparently join at the State line as components of an ancestral southerly drainage system.

In view of the pronounced development of streamline features on the upland surface, their general absence in the through valleys is striking. In considerable part, their absence may be ascribed to the fact that the valleys are floored with outwash, alluvium, and other nonglacial deposits which might obscure glacial depositional topography. Among the few places where drumlin development has taken place in the through valleys are the northerly ends of the French Creek and Findley Troughs. In Mina and Sherman Towns, the drumlin trend of the uplands extends into and locally across these troughs partially obscuring their identity. Where this is the case, the difference in relief between upland and valley bottom is generally less than 200 feet. Accordingly, it is hypothesized as an inadequately tested generalization that the trend of streamline topographic features does not continue into valleys or basins which are much deeper than the relief within the drumlin field. If this hypothesis is found to hold in other locations as well, the cause may be sought in the physical properties and dynamics at the base of the continental ice sheet.

Glacial Geology

General Statement

The loose mantle of sediments which blankets lithified Paleozoic bedrock throughout most of Chautauqua County is composed of transported materials which were deposited in their present positions during Wisconsin (the latest glacial stage) and Recent time. A minor exception to this generalization is the extreme southeastern corner of the county, where residual soils are developed on regolith which may in part predate Wisconsin time.

Continental ice sheets expanded several times during the Pleistocene Epoch, spreading into Chautauqua County, but probably never completely covering the rugged southeast corner of the county. As far as present evidence indicates, movement of the ice each time was from the area of the present Lake Erie Basin as part of the Erie lobe of the ice sheet. End moraine, ground moraine, and stratified drift of the continental ice sheet comprise the major part of the mantle and occur in belts which are progressively younger from the southeastern corner of the county northwest to the base of the escarpment at the edges of the Appalachian Plateau. Chautauqua Lake, Cassadaga Creek, and Conewango Creek occupy valleys which are partly filled with outwash and valley train deposits as well as post-glacial alluvial and lacustrine materials. Sediments laid down in local short-lived lakes imponded at the ice margin occur in conjunction with the later moraines. More extensive and continuous near-shore lacustrine deposits occur in a belt between the base of the escarpment and the shore of Lake Erie.

Table 4 shows the time-stratigraphic terminology applied to the several glacial advances and the rock stratigraphic names applied to the deposits of those advances in the following discussion. In large part, the terminology is the same as that employed in the most recent correlations in Ohio (White, 1960) and adjacent Pennsylvania (Shepps et al., 1959). Names employed in earlier literature and in adjacent areas are included for reference. The extent and distribution of these rock stratigraphic units at the surface are indicated on plate 1.

Pre-Wisconsin Deposits

RESIDUAL MANTLE

The area of a few square miles at elevations between 1,800 and 2,100 feet in the extreme southeastern corner of the county is mantled with colluvium (plate 1). The mapping of DeKalb-Leetonia soils (Morrison et al., 1914) in this driftless area in positions which, north of the drift border, might develop Lordstown-Volusia soils suggests more advanced soil development in the unglaciated area. The DeKalb soil series was mapped on thin mantle over bedrock, and is characterized by yellow to yellowish brown A_2 horizon and by more compact and mottled B horizon than occurs in the Lordstown. Contrasts between the DeKalb and the Lordstown soil series are not such as to demonstrate great difference in age. The past effectiveness of slope processes in the driftless area tends to minimize the apparent age differences of upland soils on opposite sides of the drift border.

On slopes and uplands in this area, the mantle is thin and bedrock is very near the surface. Sound bedrock exposures are rare, but soils are characteristically full of channery bits of siltstone and sandstone. The distribution of large joint blocks of conglomerate downslope from their outcrop areas is clear evidence of the effectiveness of slope processes. Part of the past movement of such blocks may well be due to accelerated slope processes under a more rigorous climate near the margin of the continental ice sheet, as described in nearby Potter County, Pa. (Denny, 1956*a*). Rock cities, boulder fields, and stone nets in adjacent quadrangles east of Chautauqua County (Clark, 1910; Muller, 1960; Smith, 1953) provide additional evidence of the former influence of periglacial conditions. It is certain, however, that slope processes continue to be effective as well at the present time.

PRE-WISCONSIN GLACIATION

In the southeastern corner of Chautauqua County, the Wisconsin terminal moraine lies along the divide between the watersheds of Conewango Creek and the Allegheny River. In order to establish the maximum extent of glaciation, careful search was made for pebbles and cobbles of exotic lithology in the area southeast of this moraine. Within a mile or so of the moraine, it was generally possible to locate a few such erratic pebbles during the course of a short search. In a shallow rill near Robin Hill Road, just west of the head of South Branch Sawmill Run, till with numerous erratics was recognized. Although inadequately exposed, the soil appeared to be more deeply developed than on adjacent Wisconsin till in similar slope position. It is considered that the isolated erratics and spotty occurrence of till southeast of the Wisconsin terminal moraine represent the attenuated deposits of a probably pre-Wisconsin glaciation. This zone corresponds to the outer-phase Illinoian of Shepps et al. (1959). Beyond the zone of attenuated drift, which is no more than a mile wide in Chautauqua County, exotic constituents were recognized only in places where postglacial stream deposition, road-building, or other nonglacial agency might better account for their presence.

Deeply notched cols with V-shaped profiles occur at the heads of a number of creeks along the Conewango-Allegheny Divide. Most striking are those at the heads of several branches of Bone Run, which originate in canyons 600 feet deep and only a few thousand feet wide at the top. These cols are clearly stream cut and apparently were cut by meltwaters imponded at the ice margin as they escaped southeast across the divide. The terminal moraine projects eastward into these cols. At the head of Bone Run, for instance, low drift knolls occur a mile east of the moraine ridge on the adjacent uplands. The significance of this fact is that the cols must already have been notched essentially to their present depth prior to maximum Wisconsin glaciation marked by this terminal moraine. In the light of evidence in adjacent counties, it seems probable that the cutting of the cols at the southeast corner of Chautauqua County occurred not during the advance to the Wisconsin terminal moraine, but during a pre-Wisconsin glaciation.

Beyond the Wisconsin drift border in northwestern Pennsylvania, Leverett (1934) distinguished drift of two pre-Wisconsin glaciations which he considered to be Kansan and Illinoian. While reserving judgment as to validity of evidence of Kansan glaciation in northwestern Pennsylvania, Shepps et al. (1959) distinguished evidence of two Illinoian glaciations, referring to them as outer- and inner-phase Illinoian. Along the Allegheny River a few miles east of the Chautauqua map area, MacClintock and Apfel (1944) identified gravel terrace remnants 100 to 180 feet above the Allegheny River as being of Illinoian age. Bryant (1955) and Muller (1960) showed that certain of these features bordered a lobe of the continental ice sheet that projected southeast across the Allegheny Valley about 5 miles north of the Pennsylvania State line. Certain terrace remnants which lie outside of this conjectured ice border seem to involve ice marginal deposition so that here, also, twofold pre-Wisconsin glaciation is suggested. All these deposits lie south and east of the Wisconsin terminal moraine and predate it, yet all appear to postdate the downcutting of the Kinzua Col by escape of water impounded during an early advance of the ice margin into the valley of the Ancestral Allegheny River (page 33). Accordingly, they suggest a long history of multiple glaciation represented by no presently recognized deposits in Chautauqua County.

Early Wisconsin Glaciation

Correlations of widely scattered fossil organic sites in Quebec (Terasmae, 1958), Ontario (Dreimanis, 1958; 1960*a*; 1960*b*), Ohio (Forsyth, 1957; LaRocque and Forsyth, 1958), and New York (MacClintock and Apfel, 1944; Muller, 1960), supported by extended-range radiocarbon dating by the Groningen (Netherlands) Laboratory, indicate a complex history of glacial fluctuation in post-Sangamon, pre-Farmdale time. Although the ice margin may be presumed to have oscillated across northern Chautauqua County more than once during this interval, no Wisconsin deposits have been recognized within the Chautauqua map area older than the Wisconsin terminal moraine, which is of late Wisconsin age (page 39).

Kent Glaciation

KENT MORAINE

The southernmost end moraine, marking the terminus of the ice sheet during late Wisconsin time, enters Chautauqua County from Cattaraugus County at a point nearly due east of Ivory. It ranges slightly west of south with an irregular, topographically controlled eastern margin at 1,900 to 2,000 feet, to pass into Warren County, Pa., near Dodge. The eastern (distal) margin is topographically prominent and coincides closely with the limit of abundant erratic material in the mantle. On the proximal or westerly border, constructional topography of the end moraine grades into the smoother surface of ground moraine.

TABLE 4. Classification of Pleistocene Deposits in Chautauqua County

TIME			MORPHOSTRATIGRAPHIC	ROCK	EQUIVALENT
PLEISTOCENE EPOCH	Wisconsin	Port Huron	Warren Beach Whittlesey Beach	Undiff. lake sediments	
			Gowanda Moraine		(12,000 B. P.)
			Lake Escarpment morainic system (includes Euclid, Painesville, Ashtabula, Girard Moraines)		Dayton Moraine (Leverett, 1895) Ashtabula Moraine (Shepps et al, 1959) (White, 1960) Valley Heads Moraine (Fairchild, 1932)
			Defiance Moraine	Hiram till	
			Lavery Moraine	Lavery till	
		Cary	Findley Moraine Clymer Moraine Kent Moraine	Kent till	(14,000 B. P.) Inner Cleveland Moraine (Leverett, 1902) Outer Cleveland Moraine (Leverett, 1902) Binghamton Moraine (MacClintock and Apfel, 1944)
		Taze			Olean Moraine (MacClintock and Apfel, 1944)
					(over 54,000 B. P.) Otto organic zones (Muller, 1960)
	Ill				Illinoian terraces and Illinoian till

The end moraine consists of a belt of irregular knolls and depressions superposed on a pre-existing rugged bedrock topography. Enclosed kettle holes occur in more level areas, but on slopes are generally somewhat modified. Knolls are commonly 15 to 25 feet high, and a few kames are considerably higher. Such a knob is the summit called Oak Hill, on which is located the tower of radio station WFTM.

Meltwaters flowing from the ice margin escaped across the divide into the valleys of Bone Run and the South Branch of Sawmill Run. The outlet into South Branch Sawmill Run was only briefly in use, for a very minor withdrawal of the ice margin exposed a lower escape route southward past Dodge.

CORRELATION

The end moraine in southeastern Chautauqua County is continuous with the Wisconsin terminal moraine in Warren County, Pa., as mapped by Leverett (1934) and Shepps et al. (1959). This moraine and its associated drift in Pennsylvania have been correlated by direct tracing, supplemented by laboratory evidence, with units referred to formerly in northeastern Ohio and Pennsylvania as Early Cary Moraine and Drift (White, 1953; Shepps, 1953; 1955). To eliminate use of a time stratigraphic term in this sense, White (1960) has recently substituted the locality name of Kent for these rock stratigraphic and morphostratigraphic units, adopting as a type area the vicinity of the city of Kent in Portage County, Ohio.

Tracing the moraine in southeastern Chautauqua County eastward, MacClintock and Apfel (1944) concluded that east of The Narrows (Randolph quadrangle, Cattaraugus County) the moraine ceases to mark the Wisconsin terminus. In reconnaissance eastward across New York, they distinguished drift of relatively high lime content, relatively shallow leaching of carbonates and unmodified constructional topography, from drift of very low lime content, deeper leaching of carbonates and somewhat greater modification of constructional topography. The former they correlated with carbonate-rich kame gravels near Binghamton, assigning to them the name *Binghamton Drift.*

In 1956, Denny questioned the existence of Binghamton till in the Elmira area, thereby casting doubt on the validity of correlation of till west of Elmira with kame deposits near Binghamton. Moss and Ritter (personal communication) have recently determined that carbonate-rich gravels occur in through valleys tributary to the Susquehanna but are missing in adjacent valleys which head on divides a short distance north of the river. This relationship gives substance to Denny's suggestion that carbonate-rich till in southern New York may be the result of incorporation of outwash gravels in the sole of the ice sheet. Merritt and Muller (1959) point out the close association of upland drift of drab lithology adjacent to valley-filling bright drift of Binghamton lithology in central New York, in situations where no creditable glacier margin could be hypothesized between the two contrasting drifts. For these reasons, serious reservation is felt (Muller, 1960) regarding long-distance correlation based on similarity of till constitution, and particularly with respect to the coarse fraction. Connally (1961) has recently proposed the locality name *Almond Moraine* for a portion of MacClintock and Apfel's Binghamton moraine south and west of the Canisteo River to avoid the pitfall of uncertain correlation.

Accordingly, although Binghamton Moraine has priority in New York, it is supplanted in present discussion by the names *Kent Moraine, Kent Till,* and *Kent Glaciation* as being based on more secure correlation. Merritt and Muller (1959) meanwhile have suggested use of the term *Binghamton Drift* in a purely lithologic sense, without necessary connotation of time equivalence, pending resolution of the "Binghamton problem" through field studies which are presently under way in the area between Chautauqua County and Binghamton.

The age of the Kent (Binghamton) Moraine in Pennsylvania is approximately demonstrated by radiocarbon dating of marl and peat collected in a bog northwest of Corry, Pa. (Droste et al., 1959). Internally consistent dates on marl and basal peat collected by drill-coring and analyzed in the U. S. Geological Survey radiocarbon laboratory, indicate recession of the ice from the Kent terminal moraine in this area prior to 14,000 B. P. (W-365) (Rubin and Alexander, 1958). This analysis affords only a minimum measure of time since recession, differing from the true age of the Kent glaciation by the unknown duration of the kettle lake prior to marl accumulation. The dating is consistent, however, with previous assignments of Kent to early Cary (Shepps et al., 1959) and Binghamton to Cary (Flint, 1953; MacClintock, 1954) or early Cary (Muller, 1957).

KENT GROUND MORAINE

No differentiation of till sheets has been established from the Kent drift border north to the divide between the St. Lawrence and Ohio watersheds.

Pedologically, this area is relatively uniform. The uplands and slopes are characterized by dominance of Erie and Langford soils, developed on acid silt loam derived from the weathering of glacial till (Feuer, 1955). In many places, one or more sandy loam layers several inches thick occur in the upper few feet of the mantle, but elsewhere the soil profile is developed directly on glacial till. Leaching of carbonates from the till matrix is complete to a depth which ranges from 3½ to 5½ feet, being partly a function of texture of the superficial soil layers. This range for the depth of leaching is intermediate between that which occurs south of the drift border and that in heavier textured till to the north.

The matrix of the unweathered till (Zone 5) is blue-gray to olive-gray, silt to sandy silt. The till is moderately to very stony. Abundant angular granules of shale and silstone make the till markedly gritty when crushed between the fingers. A platy structure is sometimes apparent with peds one half inch to one and a half inches or more in maximum dimension. Where the till is relatively thick it may be "bright" in appearance, with noticeably high proportion of igneous and limestone pebbles and cobbles. Elsewhere, the proportion of cobbles of more local derivation and yellow-brown coloration is higher.

Clymer and Findley Moraines

Between the Early Cary drift border in the southeast and the divide between the St. Lawrence and Ohio watersheds in the northwest, two, more or less continuous concentrations of constructional topography and modified drift have been mapped. Although mapped as the inner and outer members of the Cleveland Moraine by Leverett (1902), these units are not correlatable with the moraine in the southern outskirts of the city of Cleveland, Ohio, and accordingly the name *Cleveland Moraine* is not retained in this sense.

West of Chautauqua Lake, these areas consist primarily of rather massive, valley-filling deposits of washed drift and subordinate unmodified till. In the through valleys of the eastern part of the county, they consist chiefly of valley-flanking kame terraces which have been breached and destroyed across the valley flat. Each consists of several terraces marking successive recessional positions of the ice margin. The ice front was apparently very irregular and responsive to topography. Minor fluctuations in one valley were not necessarily manifested in an adjacent valley. It is difficult, and in places impossible, to trace the ice marginal deposits across the upland between valleys, suggesting that active ice movement was at this time restricted to the thicker ice in the lowlands. These characteristics are such as would result during the recession of a thinning ice mass when topography of the underlying surface increasingly controlled ice movement.

The outer of the two recessional moraines is here named the Clymer Moraine for its development as a valley stopper west of the village of Clymer. This moraine enters Chautauqua County at its southwestern corner. From this point eastward across the Clymer quadrangle, it forms the drainage divide between French and Brokenstraw Creeks. It plugs former through valleys two miles east of Cutting, two miles north of Clymer, and at Panama Station. In each case, because of the smooth rise over outwash deposits graded approximately to the moraine crest, the valley plug is relatively inconspicuous as approached from its distal margin. Particularly at the head of Little Brokenstraw Creek and in the valley south of North Clymer, a succession of kame and kame terrace deposits indicates a progressive retreat from the outermost position to the most massive accumulation, which forms the drainage divide. That the retreat was not completely uninterrupted is shown by the section exposed in a borrow pit on Brownell Branch of Brokenstraw Creek, 1½ miles south of Clymer Center. In this exposure, till over several feet of varved sediments indicates at least a minor readvance of ice into a temporary proglacial lake.

Although the Clymer Moraine forms the drainage divide in the western third of the county, it is breached by the Chadakoin River at Jamestown, and east of Falconer by Cassadaga Creek. It has not yet been possible to trace this moraine across the upland between Cassadaga and Conewango Valleys, but correlation is suggested with kame deposits near Randolph and northeast of Kennedy.

The inner of the two recessional moraines is here named the Findley Moraine for its development in the basin which encloses Findley Lake where it enters Chautauqua County from the west. Eastward across the Clymer quadrangle it corresponds closely with the northern boundary of the French Creek watershed. It forms valley plugs south of Findley Lake and north of Sherman, and is continuously traceable east to the massive kame terrace and delta deposits which constrict Chautauqua Lake at Bemus, Stow, and Giffords on the Chautauqua quadrangle. Valley-flanking kame terrace deposits which may be correlatable with the Findley Moraine occur north of Sinclairville in the valley of Mill Creek, and are extensively developed north of Conewango Valley on the west side of the valley north of Cherry Creek.

Information regarding the pattern of backwasting of the ice margin may be obtained from abandoned marginal and overflow channels which served to carry off the flow of glacial meltwater. Each such channel segment can be interpreted as indicating an imponding ice margin across the present drainage line and an exposed outlet at lower elevation down the stream course. Thus, the marked channel 3 miles west-northwest of Cherry Creek indicates that while stagnant ice blocked the West Fork of Conewango Creek upstream from Hamlet, the outlet southeast past Cherry Valley was free. South of Ellington, U. S. Route 62 follows a similar overflow channel into the headwaters of Indian Creek. Limited drainage areas at the heads of Prendergust Creek and southeast of Waits Corners similarly were reversed to flow southward into Goose Creek for a while during recession between the Clymer and Findley Moraines.

On the basis of the character of the Clymer and Findley Moraines as deposits of stagnant ice along a progressively receding ice margin, and of the relative uniformity of the ground moraine from the drift border northwest to the vicinity of the Portage Escarpment, it is inferred that these deposits mark two principal recessional positions occupied during waning at the end of the Kent glaciation.

Lavery Glaciation

The outermost and most southerly of a group of moraines near the north margin of the plateau stands in marked contrast to the stagnant ice deposits previously discussed. Nowhere is it topographically prominent, yet when approached from the south it is in many places rather distinct because of the regularity and continuity of its frontal ridge. The smoothly curving distal border of the moraine contrasts with the irregularity of the topographically controlled margins of the receding Kent ice sheet. Little outwash or modified drift are associated with the moraine. North of the end moraine, the till sheet is thin, so that bedrock is frequently exposed in drainage ditches and road cuts. The effect is suggestive of deposition by a thin, advancing ice sheet which only briefly topped the escarpment before receding to some position northward which is concealed beneath subsequent deposits.

The moraine described above enters Chautauqua County from the west about a mile west of South Ripley and is traceable northeast through Lombard and Volusia almost to U. S. Highway 17 between Mayville and Westfield. It exerts little control on drainage except that it is paralleled by minor tributaries of the larger creeks which transect it. Near the southeastern corner of the Ripley quadrangle this moraine is overridden by deposits of a subsequent more vigorous ice sheet. Eastward across the Dunkirk and Cherry Creek quadrangles, this moraine extends from beneath later deposits to elevations of 1,600 to 1,700 feet above sea level across the uplands, but at each through valley it is either overridden or washed out so that the moraine cannot be continuously traced.

The soil profiles are similar to those developed on Kent till, except that the depth of leaching of carbonates from the till matrix averages a bit shallower, commonly 3½ to 4 feet. Where oxidized, the till is yellowish brown, and it lacks the olive tones of the Kent till. Though the two are similar in texture, this till tends to be less pebbly (figure 13).

This moraine has been correlated by continuous tracing (Droste, personal communication) with a similar feature in northwestern Pennsylvania, named by Shepps (1955) the Lavery Moraine, with its typical development near the hamlet of Lavery, midway between Albion and Edinboro in Erie County, Pa. In view of the pattern of the Lavery Moraine referred to above, it is considered to mark a readvance from a position farther north to which the ice margin retreated following the Early Cary Kent glaciation.

Shepps et al. (1959) consider the Lavery glaciation to be of Middle Cary age, primarily because of a marked textural difference between it and the succeeding Defiance Moraine. In Chautauqua County, the Lavery Moraine is considered to be more closely related to the following fluctuations. Between Chautauqua and Cassadaga Troughs, the Lavery Moraine is closely associated with subsequent moraines so that its identity is in doubt. If correctly mapped, however, the Cassadaga Lakes are kettle lakes resulting from the melting out of Lavery ice buried by subsequent outwash.

Defiance (?) Glaciation

Clay till of distinctive constitution and pedologic character is mapped at the surface in two areas within the complex of moraines along the escarpment at the north margin of the plateau. The more westerly

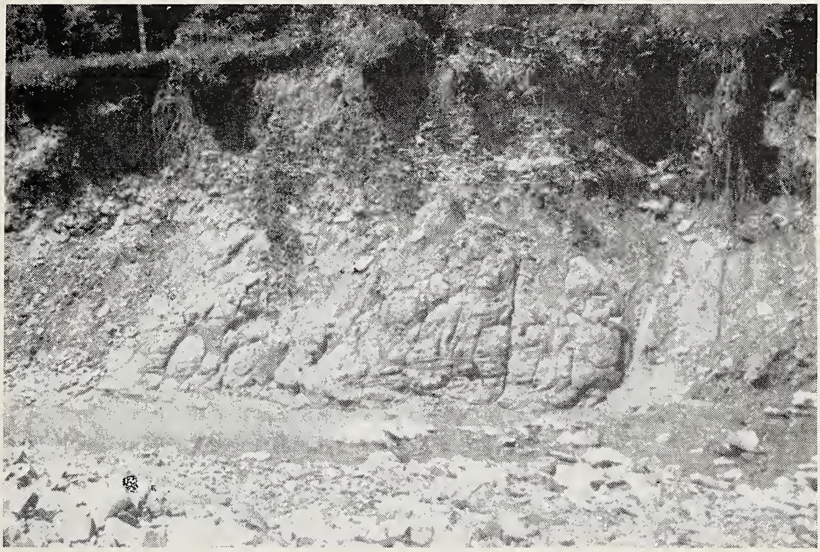

FIGURE 13. Stream-bank exposure of sparsely stony, silt till overlain by alluvial gravel. Canadaway Creek at Griswold.

occurrence of the clay till begins at the Pennsylvania border, 1½ miles west of South Ripley. It trends east, thence northeast to pass beneath a younger drift sheet 2½ miles northeast of Twentymile Creek. A second exposure of the clay till is in the through valley of Chautauqua Lake. The end moraine in this area trends generally northward from a point near Jamestown Junction. It, too, apparently passes beneath younger drift at both ends of the exposure area.

The clay till is characterized by shallow soil development which is partly a function of its fine texture and relative impermeability. Leaching of carbonate material has penetrated only 24 to 36 inches, and secondary lime deposition is observed directly beneath the leached materials. Pebbles are sparsely distributed, and the damp till is smooth when rubbed between the fingers. The oxidized zone is dark brown when damp, but on drying it quickly takes on a parched and bleached appearance. Correlation of the clay till by continuous tracing of outcrop is impossible in view of its spotty occurrence in Chautauqua County. No similar till is recognized in contiguous parts of Erie County, Pa. (Shepps et al., 1959). The writer has mapped similar till in discontinuous areas in Cattaraugus County for a distance of 20 miles east of the Chautauqua map area.

Sparsely pebbly, calcareous, gray, clay till above the Lavery drift in northeastern Ohio and Pennsylvania is mapped as Hiram till (Shepps et al., 1959; White, 1960), with type area near the village of Hiram, Portage County, Ohio. Clay till in the discontinuous exposures in Chautauqua and adjacent counties (Muller, 1956) is consistently within that part of a sand-silt-clay triangular diagram which Shepps (1953) found to be characteristic of the Hiram till. Because similarity of terrane traversed by the ice in different areas may account for textural similarity, this alone is not an adequate criterion for correlation. Pedologic resemblance of the Chautauqua County clay till and the Hiram till in its type area is partly texturally controlled and hence must be discounted as a criterion for correlation to the same extent and for the same reason as texture. In two shallow exposures in Chautauqua County, clay till occurs in superposition above the Lavery drift sheet. To demonstrate conclusively the equivalence of the clay till in Chautauqua County with the Hiram till of Ohio, it will be necessary further to show that it passes beneath distinctive drift of the moraines to the north.

End moraine associated with clay till in Chautauqua County is characterized by subdued relief. Knob and kettle topography of these moraines lacks the sharpness and steep slopes of moraine developed on gravelly materials. Closed basins are commonly 5 to 15 feet deep. Coarse-textured outwash is quantitatively unimportant, but occurs commonly as only a veneer associated with the clay till. The limit of Hiram till in northeastern Ohio is marked approximately by the Defiance Moraine, but farther west the two are not coterminous. In view of the topographic similarity of the clay till moraines in New York to the Hiram till, and the association of Hiram till in northeastern Ohio with the Defiance Moraine, it is tempting to correlate the two patches of clay till end moraine in Chautauqua County as Defiance (?) Moraine. However, the possibility exists that the clay till in Chautauqua County is instead a valley facies of one or another of the late Cary moraines and owes its distinctive character entirely to assimilation of proglacial lake sediments deposited initially in a trunk valley.

Lake Escarpment Glaciation

A group of moraines closely related to each other and to the Defiance (?) Moraine described above, occurs along the escarpment at the north margin of the Appalachian Plateaus in Chautauqua County. Distinguishing of separate moraine ridges of this compound moraine is difficult in Chautauqua County because they occur in close succession, one almost on top of the other. Westward in Pennsylvania, the ridges diverge gradually and each in turn is truncated at the shoreline of proglacial Lake Whittlesey. In this area, Leverett (1902) named the moraine ridges in succession from oldest to youngest (south to north), the Euclid, Painesville, Ashtabula, and Girard Moraines. Still younger, and located in the northeastern portion of Chautauqua County is the Gowanda Moraine, which, for purposes of this report, is associated with the four moraines named above.

Because of the difficulty of tracing individual moraine ridges, a name is necessary for the moraine system as a group. Leverett (1895) applied the name Dayton Moraine to the massive valley-stopper moraine at the village of Dayton, N. Y., just east of the border of the Chautauqua map area. Later (1902), in recognition of the complexity of the belt, he supplanted this name by the term *Lake Escarpment Morainic System.* The physiographic implications of this name are appropriate in Chautauqua County, but eastward the association of the moraines with the escarpment becomes invalid. Shepps et al. (1959) following White (1960) adopted the name *Ashtabula Moraine* for the group of moraines, redefining a term initially applied by Leverett to a single moraine ridge. In the interest of continuity and simplicity, Leverett's terminology is here retained for Chautauqua County in preference to that adopted in Pennsylvania and Ohio.

The Lake Escarpment Moraines are characterized by strong topographic expression with conspicuous kame knobs and kettle depressions. Several parallel ridges mark the southern margin of the belt, suggesting an oscillatory condition along the ice front near its maximum position. The most southerly moraine ridges rise generally northeastward from more than 1,200 feet at the Pennsylvania border to 1,500 to 1,700 feet where the ice abutted against northward projecting ridges in the northeastern portion of the county. Toward the base of the escarpment, the crowded moraine ridges spread enough for the development of sag and swell ground moraine topography between ridges. In places on the lower slopes the unconsolidated mantle is very thin, having been eroded by meltwaters. In eastern Dunkirk quadrangle and in the Cherry Creek quadrangle, the two most northerly moraines are marked more conspicuously by marginal meltwater channels paralleling the face of the escarpment than by remnants of ice marginal deposits.

Correlation of the Lake Escarpment Moraine belt with the Valley Heads Moraines of central New York, as suggested by Fairchild (1932), MacClintock (1954), and others, is supported by current investigations. Radiocarbon dating of spruce wood from marly silt overlying outwash gravel near a mastodon site in the southeastern corner of Erie County, N. Y., yields a minimum age of 12,020 (W-507) for recession from the terminal moraine. The topographic situation is such that marl could not have begun to accumulate until after glacier recession had started. Accordingly, the date obtained should closely follow the maximum extent of Lake Escarpment ice. Confirmatory evidence indicative of rapid recession is found in the 11,410 B.P. date of wood (Y-460) associated with mastodon remains on the Colgan farm north of King Ferry near Cayuga Lake and 30 miles north of the Valley Heads terminus. A suggestion that both these dates may be measurably younger than the Valley Heads maximum is afforded by analysis of spruce from proglacial lake deposits at Lewiston, N. Y. Following an analysis with suspected background interference which yielded an unduly young date, two reruns (W-861 and W-883) yielded an average of 12,370 years B.P. On the basis of these data, the Lake Escarpment Moraines are presently considered to be of late Cary age and probably are in part equivalent to the Port Huron Moraine of Michigan.

Lake Sediments

Unconsolidated sediments deposited in former lakes are widely distributed in lowland areas of Chautauqua County and comprise an important part of the fill in a number of the through valleys. Some of these sediments represent lakes produced by drainage derangement during pre-Wisconsin glaciation, and are known only through records of gas and water wells. Some existed at the margin of the Wisconsin ice sheet, imponded as proglacial lakes between the glacier edge and the higher land of the plateau. Others were deposited in lakes presently shrunken by lowering of their outlets or filled by postglacial sedimentation.

Drillers' records for wells in Conewango, Cassadaga, and Chautauqua Troughs commonly record thick sections of "clay." In Conewango Trough, near Markham, gas wells drilled a half century ago penetrated nearly 1,000 feet of unconsolidated sediment without encountering bedrock. Drift encountered in these wells included several sections which are apparently of lacustrine origin. A well along Flatiron Road near the Leon-Conewango town line, drilled in 1961, penetrated 216 feet of "clay" and 234 feet of "clay, silt and sand" before striking a large log at 583 feet which prevented further drilling (L. J. Crain, U. S. Geol. Survey, personal communication). Clay till and fine-textured lake sediments are commonly difficult to distinguish even in fresh surface exposures and are less distinguishable in the subsurface. Nevertheless, it is reasonable to accept at face value the probability that much of the sediment described is lacustrine. There can be little doubt that the large log is of interglacial origin and beyond the range of present radiocarbon dating methods.

Accordingly, we are faced with the seeming contradiction that Conewango Trough, though externally of glacial form, is deep enough to preserve pre-Wisconsin sediments which elsewhere would have been obliterated by subsequent glaciation. In few places in New York will detailed accumulation and analysis of subsurface data potentially provide as much new data on Pleistocene environments and history as in the Conewango Trough.

Sediments which accumulated in lakes adjacent to the ice margin commonly display a rhythmic alternation of light and dark, or silty and clayey laminae. Where the sedimentary pairs in such rhythmic lamination can be shown to represent seasonal changes during the annual cycle, they are properly called varves. Unless this relationship can be demonstrated, the less specific term "rhythmite" is preferable.

In Chautauqua County, rhythmite beds have been noted as deposits in short-lived lakes marginal to a stagnating ice tongue, and as proglacial lakes imponded in front of the ice. Representative of the former group are laminated silt and clay beds which crop out along Canadaway Creek near Griswold (figure 14) along Clear Creek near Ellington and in Mud Creek southwest of Leon. In all three cases the exposures are too limited to appear on the glacial map (plate 1).

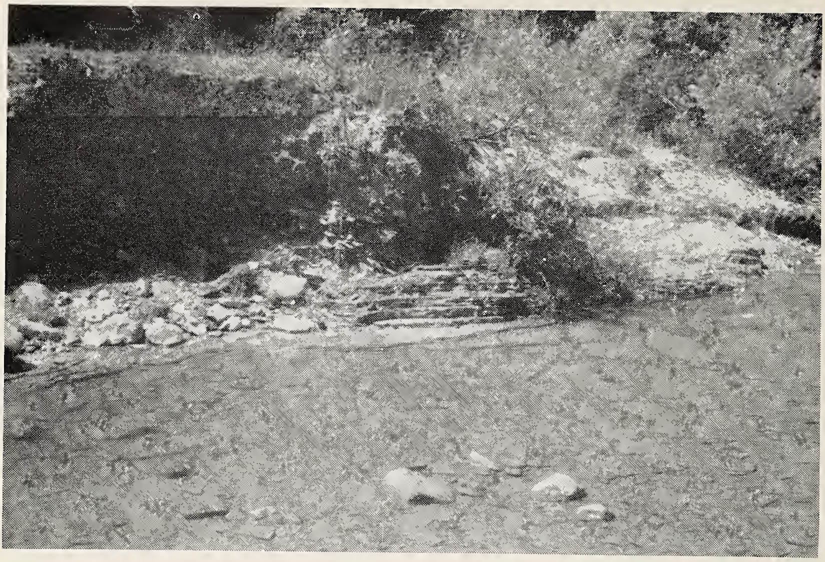

FIGURE 14. Laminated lake sediments exposed at stream level beneath alluvial terrace gravel in bank of Canadaway Creek, east of Griswold.

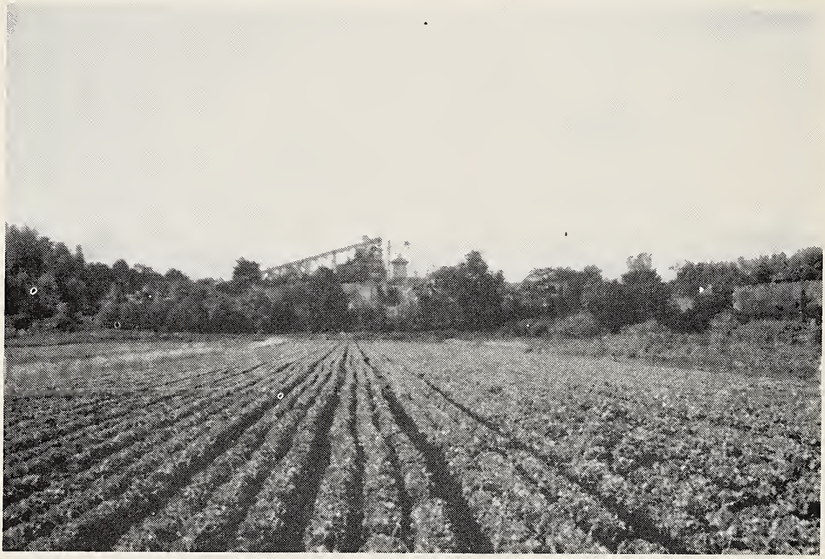

FIGURE 15. View south near Celoron, showing economic aspects of two features of the surficial geology. Lettuce in foreground is a profitable crop on the muckland which marks the former extent of Chautauqua Lake. In the distance, gravel is produced from a Pleistocene kame terrace.

Proglacial lakes were imponded in each re-entrant of the scarp as the glacier thinned against the plateau margin. Relatively extensive areas of exposure of such proglacial sediments are north of the outermost Lake Escarpment Moraine in the headwaters of Chautauqua, Walnut, and Canadaway Creeks. The levels of each proglacial lake were controlled by the lowest available outlet marginal to, beneath, or away from the glacier. Some of the more prominent channels aligned parallel to the contour along the scarp are mapped (plate 1). Oscillatory conditions of the ice margin in such circumstances might markedly alter depositional environments. In a bluff cut by Thatcher Brook, south of Gowanda, just outside the northeast corner of the Chautauqua map area, four successive tills separated in exposure by proglacial lake sediments are ascribed to such oscillatory retreat (Muller, 1960).

As the ice sheet waned during late Wisconsin time the Ancestral Great Lakes came into existence. Two predecessors of Lake Erie were Lakes Whittlesey and Warren, which had their outlets through the Maumee River in Ohio and the Illinois River, respectively. Unlike the other glaciomarginal lakes mentioned above, Lakes Whittlesey and Warren were long enough enduring and extensive enough to develop pronounced shore features which were among the first Pleistocene land forms recognized and described in the area. The two strandlines are rather readily traceable across Chautauqua County (figure 6). In this distance of about 40 miles they rise eastward about 50 feet, an evidence of upwarping due to postglacial isostatic adjustment.

The basin of Beaver Brook north of Cutting is representative of a lake filled in by postglacial sedimentation, while Chautauqua Lake is an example of a body of water reduced in extent by downcutting of the outlet. Muckland farming on the western outskirts of Jamestown (figure 15) is possible today because of the shrinkage of Chautauqua Lake as Chadakoin Creek cut into the kame deposits at Jamestown. Municipal wells, drilled for water in this area, penetrated 34 feet of muck over 160 feet of "clay" and 36 feet of glacial sediments before encountering bedrock at 230 feet.

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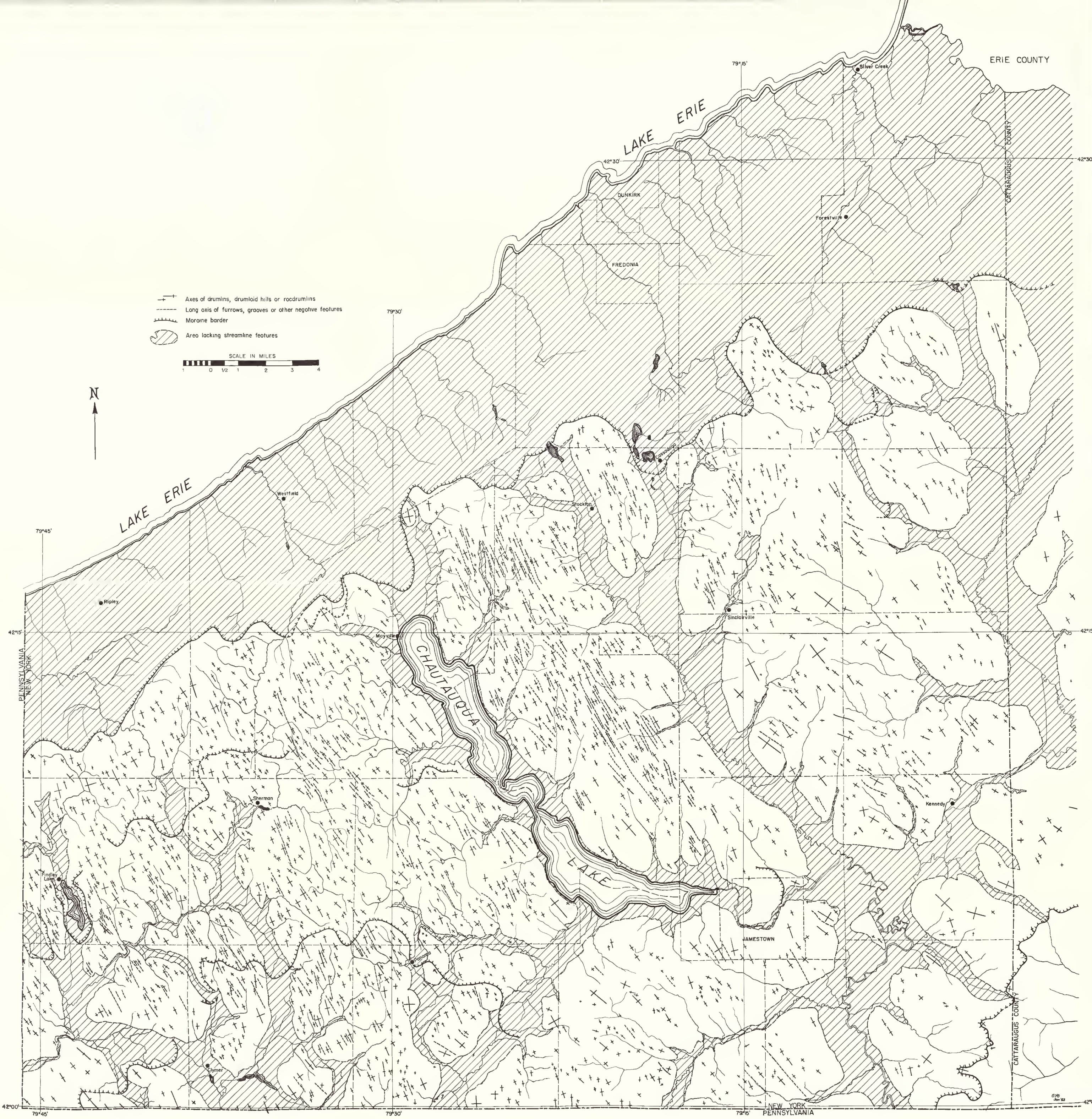


Figure 8. Map of Chautauqua County Showing Generalized Flow Lines as Indicated by Striae and Streamline Topographic Features

STRATIGRAPHIC OCCURRENCE OF FOSSILS IN CHAUTAUQUA COUNTY, NEW YORK

	ANGOLA	PIPE CREEK	HANOVER	DUNKIRK	SOUTH WALES	GOWANDA	LAONA	WESTFIELD	SHUMLA	NORTHEAST	DEXTERVILLE	ELLICOTT	CATTARAUGUS	KNAPP
THALLOPHYTA														
ALGAE			×	×	×	×								
CONIFEROPHYTA														
Callixylon cf. *newberryi* ELKINS & WIELAND										×	×	×	×	
OTHER CARBONIZED STEMS								×						
PLANT (?)														
Taonurus? sp.									×					
PORIFERA (?)														
Clianalithes palmatus CLARKE						×								
BRYOZOA														
spp. not determined							×			×	×	×	×	
BRACHIOPODA														
Ambocaelia gregaria HALL							×			×	×	×	×	
Athyris angelica HALL							×			×	×	×		
Camarataechia cantracta (HALL)							×	×		×	×	×	×	
C. sappha (HALL)												×	×	
Cariniferella tiaga (HALL)							×							
Chanetes cf. *lepidus* HALL							×							
C. scitulus HALL										×		×	×	
Cyrtaspirifer cf. *harnellensis* GREINER												×		
C. inermis (HALL)							×					×		
C. nucalis GREINER											×	×		
C. tianesta GREINER													×	
Leiarhynchus cf. *mesacastalis* HALL												×	×	
Lingula cf. *melie* HALL										×				
Petracrania leanis (HALL)							×			×				
Productella cf. *hirsuta* HALL												×	×	
P. lachrymasa (CONRAD)										×		×		
P. cf. *anusta* HALL											×	×	×	
P. speciasa HALL										×	×	×		
Pugnaides duplicatus (HALL)											×			
Schellwienella chemungensis (CONRAD)										×				
Straphapraductus hystriculus (HALL)							×			×	×	×		
Thiemella tenuilineata (HALL)							×			×	×	×		
T. villenavia WILLIAMS										×				
Tylathyris mesacastalis (HALL)							×							
PELECYPODA														
Aviculapecten cancellatus HALL										×	×			
Buchiala cf. *angalensis* CLARKE						×								
B. conversa CLARKE						×								
Crenipecten lean HALL										×				
Edmandia cf. *philipi* HALL							×							
E. rhambaidea HALL													×	
Elasmatium gawandense CLARKE						×								
Euthydesma subtextile HALL						×								
Grammysia undata HALL													×	
Kachia ungula CLARKE						×								
Leiapteria tarreyi HALL													×	
Leptadesma patens HALL												×	×	
L. saciale HALL										×		×	×	
Laxapteria carrugata CLARKE						×								
L. dispar (SANDBERGER)						×								
L. intumescentis CLARKE						×								
L. laevis FRECH						×								
L. vasta CLARKE						×								
Lunulicardium absegmen CLARKE						×								
L. accala CLARKE						×								
L. beushauseni CLARKE						×								
L. eriense CLARKE						×								
L. furcatum CLARKE						×								
L. libum CLARKE						×								
Lyrlapecten fasciatus HALL										×				
L. salax HALL													×	
Madiala metalla HALL													×	
Mytilarca chemungensis (CONRAD)							×			×	×	×		
M. cf. *gibbasa* HALL													×	
M. regularis HALL										×				
Nucula glabularis HALL													×	
Ontaria cancentrica (VON BUCH)						×								
Palaeanatina cf. *angusta* HALL											×		×	
P. cf. *typa* HALL										×				
Palaeaneila canstricta (CONRAD)						×				×				
P. cf. *elangata* HALL													×	
P. linguata CLARKE						×								
Paralleladan chemungensis (HALL)										×				
Pararca erecta HALL													×	
Pasidania mesacastalis (WILLIAMS)						×								
P. venusta var. *nitidula* CLARKE						×								
Praecardium melletes CLARKE							×							
P. multicastatum CLARKE						×								
P. vetustum HALL						×								
Pteranites prafundus HALL							×							
Ptychopteria eucrate HALL													×	
P. cf. *galene* HALL													×	
P. saa HALL													×	
P. cf. *sinuasa* HALL													×	
P. triganalis HALL													×	
Sanguinalites undulatus HALL										×	×			
Schizadus rhambeus HALL													×	
Sphenatus arcuatus HALL													×	
S. cantractus HALL							×			×				
GASTROPODA														
Carinarapsis? chautauquae (CLARKE)						×								
Euryzane itylus (CLARKE)						×								
Laxanema danai CLARKE						×								
Straparalus hecale HALL										×	×		×	
CEPHALOPODA														
Aulatornaceras clarkei (MILLER)						×								
"Orthaceras" sp.													×	
MOLLUSCA *(incertae sedis)*														
Hyalithes neapalis CLARKE						×				?				
CRINOIDEA														
Scytalacrinus arnatissimus (HALL)						×								
spp. not determined							×			×	×	×	×	
CONODONTA														
Ancyragnathus bifurcata (ULRICH & BASSLER)					×	×		×	×					
A. euglyphea STAUFFER			×											
Neaprianiodus mutabilis (BRANSON & MEHL)								×	×			×		
Palmatadella delicatula ULRICH & BASSLER						×		×						
Palmatalepis distarta BRANSON & MEHL												×		
P. glabra ULRICH & BASSLER					×	×		×	×					
P. perlabata ULRICH & BASSLER						×		×	×					
P. subperlobata BRANSON & MEHL						×		×	×					
P. subrecta MILLER & YOUNGQUIST			×	×										
Palygnathus semicastata BRANSON & MEHL									×			×		
Palylaphadanta canfluens (ULRICH & BASSLER)												×		
FISH														
spp. not determined							×							

Table 1

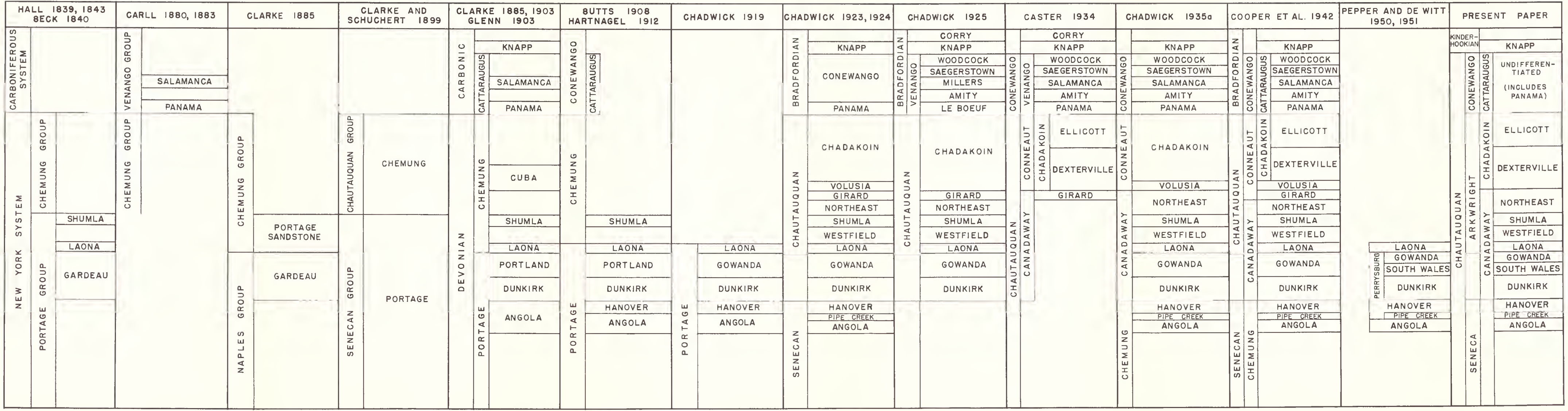

HALL 1839, 1843 BECK 1840
CARBONIFEROUS SYSTEM
NEW YORK SYSTEM
CHEMUNG GROUP
PORTAGE GROUP
SHUMLA
LAONA
GARDEAU
CARLL 1880, 1883
VENANGO GROUP
CHEMUNG GROUP
SALAMANCA
PANAMA
CLARKE 1885
CHEMUNG GROUP
NAPLES GROUP
PORTAGE SANDSTONE
GARDEAU
CLARKE AND SCHUCHERT 1899
CHAUTAUQUAN GROUP
SENECAN GROUP
CHEMUNG
PORTAGE
CLARKE 1885, 1903 GLENN 1903
CARBONIC
DEVONIAN
CATTARAUGUS
CHEMUNG
PORTAGE
KNAPP
SALAMANCA
PANAMA
CUBA
SHUMLA
LAONA
PORTLAND
DUNKIRK
ANGOLA
BUTTS 1908 HARTNAGEL 1912
CONEWANGO
CHEMUNG
PORTAGE
CATTARAUGUS
SHUMLA
LAONA
PORTLAND
DUNKIRK
HANOVER
ANGOLA
CHADWICK 1919
PORTAGE
LAONA
GOWANDA
DUNKIRK
HANOVER
ANGOLA
CHADWICK 1923, 1924
BRADFORDIAN
CHAUTAUQUAN
SENECAN
KNAPP
CONEWANGO
PANAMA
CHADAKOIN
VOLUSIA
GIRARD
NORTHEAST
SHUMLA
WESTFIELD
LAONA
GOWANDA
DUNKIRK
HANOVER
PIPE CREEK
ANGOLA
CHADWICK 1925
BRADFORDIAN
VENANGO
CHAUTAUQUAN
CORRY
KNAPP
WOODCOCK
SAEGERSTOWN
MILLERS
AMITY
LE BOEUF
CHADAKOIN
GIRARD
NORTHEAST
SHUMLA
WESTFIELD
LAONA
GOWANDA
DUNKIRK
CASTER 1934
CONEWANGO
VENANGO
CONNEAUT
CHADAKOIN
CHAUTAUQUAN
CANADAWAY
CORRY
KNAPP
WOODCOCK
SAEGERSTOWN
SALAMANCA
AMITY
PANAMA
ELLICOTT
DEXTERVILLE
GIRARD
CHADWICK 1935a
CONEWANGO
CONNEAUT
CANADAWAY
CHEMUNG
KNAPP
WOODCOCK
SAEGERSTOWN
SALAMANCA
AMITY
PANAMA
CHADAKOIN
VOLUSIA
NORTHEAST
SHUMLA
WESTFIELD
LAONA
GOWANDA
DUNKIRK
HANOVER
PIPE CREEK
ANGOLA
COOPER ET AL. 1942
BRADFORDIAN
CHAUTAUQUAN
SENECAN
CONEWANGO
CONNEAUT
CANADAWAY
CHEMUNG
CATTARAUGUS
CHADAKOIN
KNAPP
WOODCOCK
SAEGERSTOWN
SALAMANCA
AMITY
PANAMA
ELLICOTT
DEXTERVILLE
VOLUSIA
GIRARD
NORTHEAST
WESTFIELD
LAONA
GOWANDA
DUNKIRK
HANOVER
PIPE CREEK
ANGOLA
PEPPER AND DE WITT 1950, 1951
PERRYSBURG
LAONA
GOWANDA
SOUTH WALES
DUNKIRK
HANOVER
PIPE CREEK
ANGOLA
PRESENT PAPER
KINDERHOOKIAN
CHAUTAUQUAN
SENECA
CONEWANGO
ARKWRIGHT
CANADAWAY
CATTARAUGUS
CHADAKOIN
KNAPP
UNDIFFERENTIATED (INCLUDES PANAMA)
ELLICOTT
DEXTERVILLE
NORTHEAST
SHUMLA
WESTFIELD
LAONA
GOWANDA
SOUTH WALES
DUNKIRK
HANOVER
PIPE CREEK
ANGOLA

Figure 4. Historical Development of Chautauquan Nomenclature in Chautauqua County

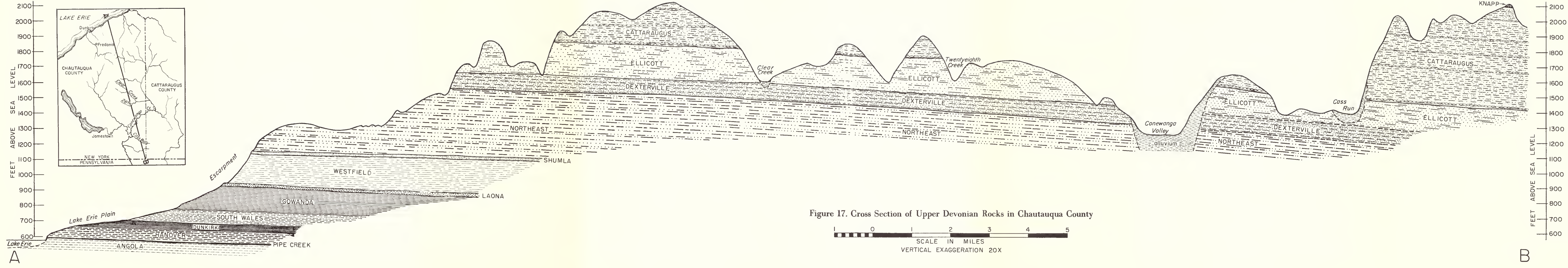


Figure 17. Cross Section of Upper Devonian Rocks in Chautauqua County

Q
11
N82X
NH
No. 391

507.73
N7N75

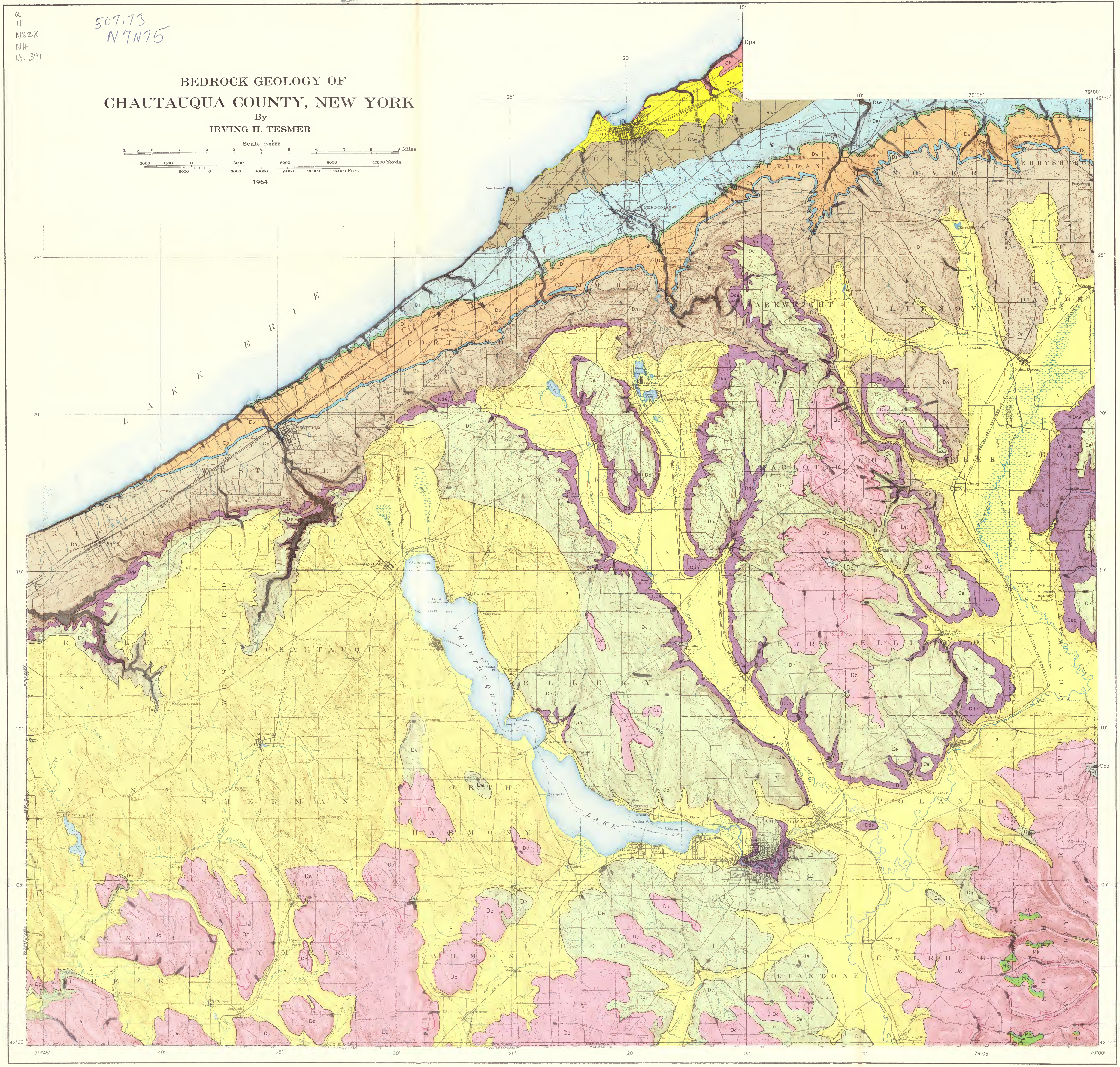
BEDROCK GEOLOGY OF
CHAUTAUQUA COUNTY, NEW YORK

By

IRVING H. TESMER

Scale $\frac{1}{125000}$

1964



EXPLANATION

QUATERNARY

S

Surficial Deposits
Thick cover of unconsolidated surficial deposits of Pleistocene and Recent ages

MISSISSIPPIAN

Mk

Knapp Conglomerate
Rounded pebbles of milky quartz imbedded in a dark gray siliceous matrix

UPPER DEVONIAN

Dc

Cattaraugus Formation, undifferentiated
Interbedded medium gray siltstone and shale with occasional redbeds; various conglomerate lenses are indicated by red lines

De

Ellicott Shale
Medium gray shale with some interbedded medium gray siltstone

Dde

Dexterville Siltstone
Medium gray siltstone with some interbedded medium gray shale

Dn

Northeast Shale
Medium gray shale with some interbedded medium gray siltstone to the east

Ds

Shumla Siltstone
Medium gray siltstone with some interbedded medium gray shale

Dw

Westfield Shale
Medium gray shale with some interbedded medium gray siltstone

Dl

Laona Siltstone
Medium gray siltstone with some interbedded medium gray shale

Dg

Gowanda Shale
Medium gray shale with some dark gray to black shale near base and some interbedded medium gray siltstone

Dsw

South Wales Shale
Medium gray shale with some interbedded medium gray siltstone; several concretionary zones

Ddu

Dunkirk Shale
Dark gray to black shale with a few large septaria

Dh

Hanover Shale
Medium gray shale with some dark gray to black shale; some thin siltstones and limestones as well as several concretionary zones

Dpa

Pipe Creek Shale and Angola Shale, undifferentiated
Massive black shale overlying medium gray shale with a little dark gray to black shale; some thin siltstones and limestones; several concretionary zones

●

Outcrop Area

GEOLOGIC MAPPING 1947-1959

Williams & Heintz Map Corporation, Washington, D. C. 20027

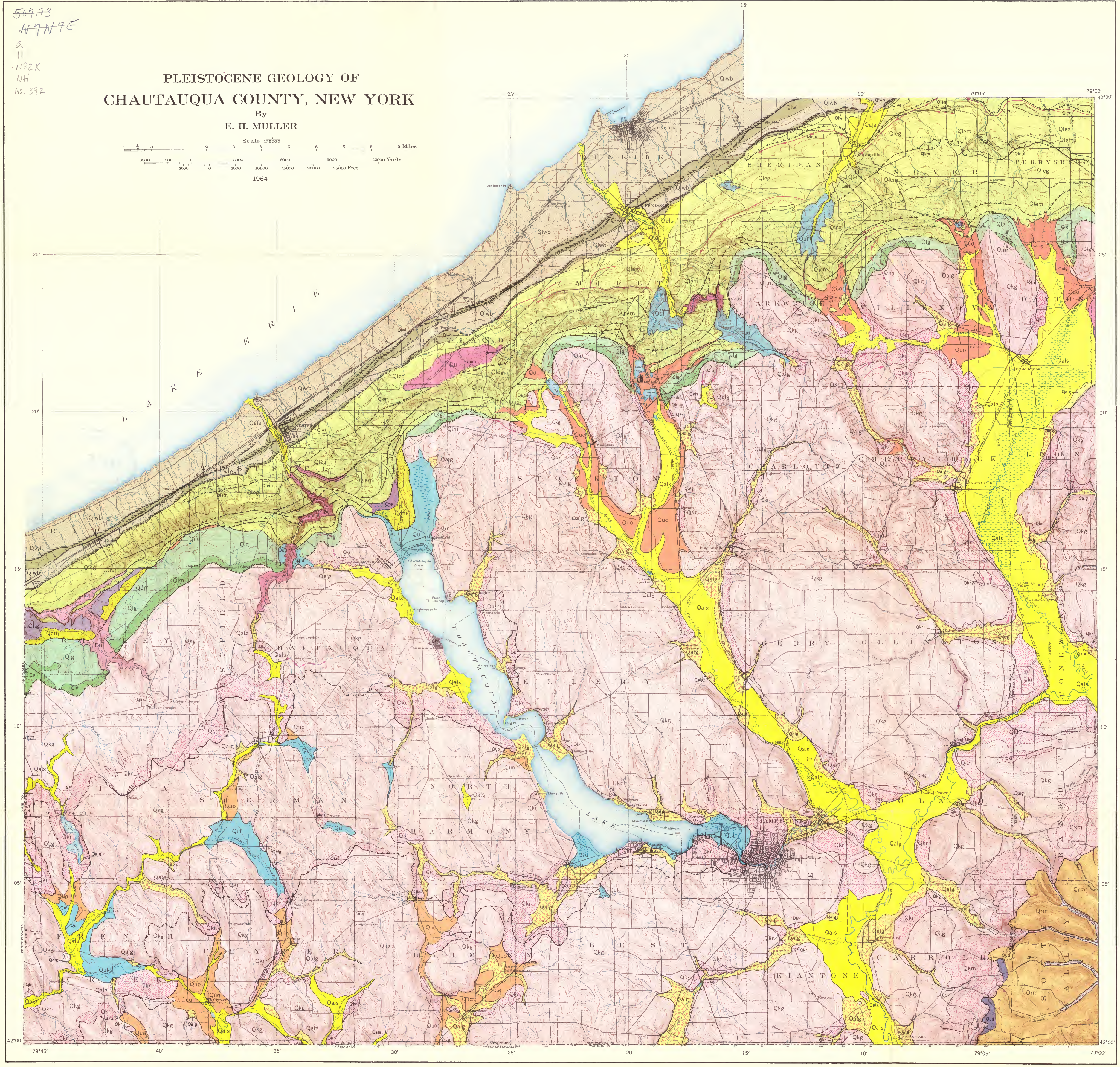
~~564.73~~
~~N7N75~~
Q
11
N82X
NH
No. 392

PLEISTOCENE GEOLOGY OF
CHAUTAUQUA COUNTY, NEW YORK

By
E. H. MULLER

Scale $\frac{1}{125000}$

1964



EXPLANATION

RECENT

Stream deposits

Qalg
Alluvium, dominantly gravel

Qals
Alluvium, dominantly sand and silt

WISCONSIN

Late Cary

Sediments of Lakes Whittlesey and Warren

Qlwl
Littoral sediments

Qlwb
Bottom sediments

Lake Escarpment glaciation

Qlem
End moraine

Qleg
Ground moraine

Defiance (?) glaciation

Qdm
Defiance (?) end moraine

Qhg
Hiram (?) ground moraine

Lavery glaciation

Qlm
End moraine

Qlg
Ground moraine

Kent glaciation

Early Cary

Qkm
End moraine

Qkg
Ground moraine

Qkr
Findley and Clymer recessional moraines and stratified drift

Pre-Cary

Qrm
Residual mantle and congeliturbate

Undifferentiated as to age

Quo
Outwash

Qul
Proglacial and post-glacial lake sediments

Qud
Attenuated drift

Du
Less than 3 feet of drift over bedrock

SYMBOLS

Border of ice sheet (hachured toward glacier)	Probable	Inferred
Strand of proglacial lake (hachured toward lake)	Probable	Inferred
Glacial meltwater channel (showing direction of flow and present elevation of col)	→	

GEOLOGIC MAPPING 1955-1956

Williams & Heintz Map Corporation, Washington, D. C. 20027

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